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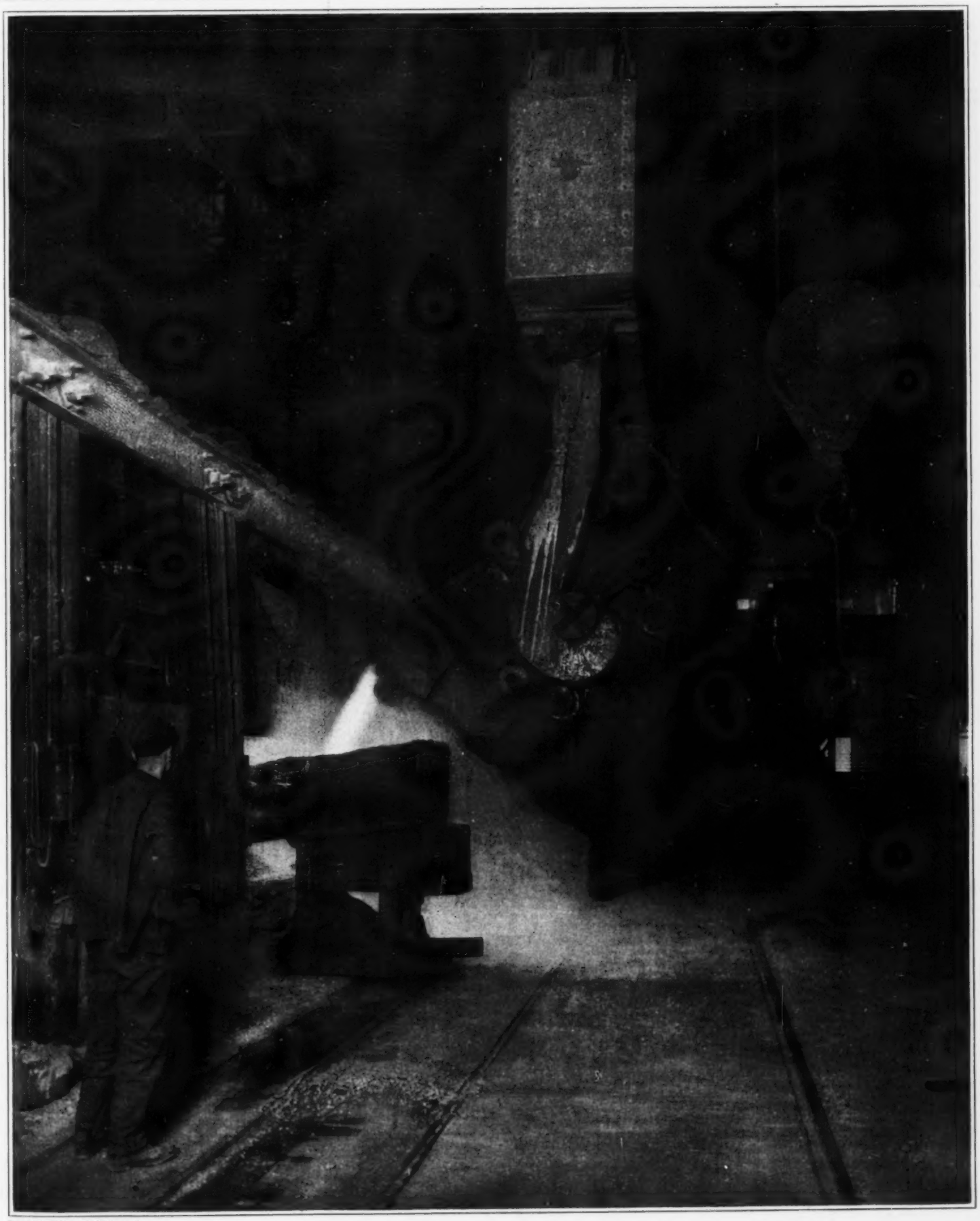

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Pouring melted iron into a converter that makes it into steel

TYPICAL SCENES IN A STEEL PLANT [See page 376]

The Rise of Navigation*

Slow Steps by Which the Science Has Been Developed

R. H. Curtiss

ONE of the most obvious practical benefits directly traceable to astronomical research is found in the application of celestial observations to the solution of the problems of navigation. Though other sciences have contributed their quota, it is mainly astronomy that has made the ocean safe for the navigator.

The fundamental problem of Navigation is: Given the position on the earth of the port to be reached, to determine the ship's positions and the best courses to be steered at suitable intervals from the beginning to the consummation of the voyage. This problem, so important commercially, is strictly speaking one of science, for it depends chiefly for its accurate solution on the application of the principles and methods of practical astronomy.

For obvious reasons the accuracy attainable in determinations of position and direction at sea is much inferior to that possible on shore. The unsteadiness of the platform of a ship, the uncertainties of atmospheric refraction near or on the horizon, and the intervention of cloudy periods while the ship is progressing through disturbing currents and winds are formidable difficulties which the navigator must meet. But the results attainable with care leave only a small element of risk affecting modern transportation at sea.

Quite different was the position of the navigator in early times. The compass was introduced generally into Europe about 1400 A. D. Before this time the only practical means of navigating a ship on the Atlantic and Mediterranean was to keep in sight of land, or occasionally, for short distances, to direct the ship's course by reference to the sun and stars. But this very rough method failed in cloudy weather, and even during short voyages on the Mediterranean in such circumstances the navigator became hopelessly bewildered as to his position. Frequently, on the China Sea and the Indian Ocean, vessels were able to traverse long distances out of sight of land by running directly before the steady winds, called the monsoons, which prevail in those localities. But the compass was an important adjunct even there, and such methods of navigating were makeshifts at best.

The general adoption of the mariner's compass, about 1400 A. D., was followed by a period of progress in Navigation, particularly among the Portuguese, whose exploring expeditions during the fifteenth century led to important discoveries in the Atlantic. Prior to this time the methods in use were very rude, uncertain and dangerous. When a fleet of merchant vessels was sent to distant ports the trader was content if one or two returned and he fixed the prices on his precious imports accordingly.

But even at the beginning of the seventeenth century Navigation was still in a very backward state. That the compass needle does not point true north had been noticed early; that the amount of variation from north was different for different localities had been noted by Columbus or Cabot about 1490; but that the variation of the compass changes from year to year at the same base was not known until 1635.

At this time (about 1600) a navigator's equipment included: a compass for directing the course; a rough weight and line for making soundings; a cross-staff or astrolabe for measuring angles; a fairly good table of the Sun's distance north or south of the equator; and corrections for the altitude of the pole star. The last four appliances were used solely to determine the latitude or the distance on the earth's surface north or south of the terrestrial equator. Occasionally a very incorrect chart helped determine the ship's position. In this connection the motion of the ship was usually determined by estimating the speed every two hours or so, or, in some cases, by throwing out a float from the bows of the ship and noting the interval of time between its passage abeam of two observers standing on the deck at known distances apart.

By observations with the cross-staff and astrolabe on the Sun or the pole star, latitude could be measured at sea with sufficient accuracy to fix the observer's position north or south of the equator within twenty miles or so, but no method was available for finding longitude or position east or west on the earth, except the rough expedient of estimating the run of the ship, taking wind, tide, and current into account. The only mode of arriving at a port of destination was to steer so as to get into the latitude of such a port either to the eastward or westward of its supposed position, and then to approach it on its parallel of latitude by steering a course due east or west. Obviously this method, though the best then available, might prove fatal if the error in longitude were too great.

The advice on longitude finding given by a nautical authority of repute at this time illustrates well the status of the problem up to the eighteenth century. He observes, "Now there be some that are very inquisitive to have a way to get the longitude, but that is too tedious for seamen, since it requireth the deep knowledge of Astronomy, wherefore I would not have any man think that the longitude is to be found at sea by any instrument; so let no seamen trouble themselves with any such rule, but (according to their accustomed manner) let them keep a perfect account and reckoning of the way of their ship." Such a record of the way of a ship appears to have been made with chalk on a wooden board called a log board which folded like a book and from which each day a position for the ship was deduced.

But while the longitude problem at sea remained unsolved, contributions to progress in Navigation were being made in other directions. Mercator and Wright developed a correct sailing chart about 1600. Gunter's tables in 1620 made possible the application of logarithms to Navigation. In 1631 a device, called the vernier, for accurate reading of scales became known. In 1635 Gellibrand published his discovery of the annual change in the variation of the compass needle. In 1637 Norwood helped remove one of the greatest stumbling blocks in the way of correct navigation by determining improved values of the length of a minute of arc on the earth's surface, or the true nautical mile. His value was about six per cent. too large. In 1699 Halley constructed the first compass variation chart.

In the meantime some progress was being made with the longitude problem. It was recognized that the only accurate method of determining the longitude is by knowing the difference at the same instant between the time at the meridian of Greenwich and that of the observer. The determination of the local time for the observer by astronomical observations of the altitude of suitably situated heavenly bodies was an old, well-known and frequently practiced operation. But the simultaneous determination of Greenwich time presented great difficulties. Obviously if the ship were near enough to a station on the Greenwich meridian a rocket or a loud explosion could be used as a signal at some stated Greenwich time. The ship's time for the same instant could then be observed and the difference between these two times for the same instant would be the longitude of the ship east or west of Greenwich. But for ships out of signal range from Greenwich observations of celestial phenomena had to be employed. At present chronometers are carried on board ship which, after being corrected and rated at departure, keep accurate Greenwich time throughout the voyage and thus render longitude determination relatively easy. But chronometers of satisfactory accuracy were not available till late in the eighteenth century.

The best method known for determining Greenwich time at sea by observation before the chronometer became available was that depending upon the measurement of the distance of the Moon from selected stars. For the Moon makes a rapid circuit of the sky once each month and in so doing passes close to a number of bright stars. Hence if the navigator can be provided with tables giving the Greenwich time when the Moon should be found to be distant from a given star by a given amount which he has measured, then the Greenwich time of the instant of that observation becomes known and may be kept by an hour glass or watch for a few minutes while the ship's time is being found.

This method for determining longitude was foreseen as early as 1514 but its practical application was attended with difficulties, not surmounted indeed before another and better method had been developed through the invention of the accurate chronometer. The difficulties in the way of the lunar distance determination of longitude were imperfect knowledge of the Moon's motion and the crude character of the instruments for measuring angles, together with some inferiority inherent in the method.

The study of the longitude problem was stimulated by a prize of 1,000 crowns offered by Philip III of Spain, followed by another of 10,000 florins by the States-general for the discovery of a method of finding longitude at sea. As a result it was brought out that methods depending on the Moon's position offered the best solution at that time but that the lunar tables extant were useless and that much study and observation would be necessary to make them available. Primarily to attack this lunar problem England established her national observatory, in 1675. Fifty-six years later the Astronomer Royal in charge of the Greenwich Observatory announced that he hoped to be able to compute the Moon's position within such limits that longitude errors would be reduced to sixty miles at the equator. Apparently progress had been slow.

In 1714 England's "Commission for the discovery of longitude at sea" had been constituted with power to grant large sums in prizes. For a method of determining the longitude within sixty geographical miles, to be tested by a voyage to the West Indies and back, ten thousand pounds was offered; within forty miles, fifteen thousand pounds; within thirty miles, twenty thousand pounds.

The importance of further progress in methods of Navigation at this time is brought out by accounts of actual casualties showing what the dangers were. Admiral Wheeler's squadron, in 1694, leaving the Mediterranean, ran on Gibraltar when they thought they had passed the Strait. Sir Cloudlesley Shovel's squadron, in 1707, was lost on the rocks off Scilly, by erring in their latitude. Several transports, in 1711, were lost near the St. Lawrence river, having erred forty-five miles in their reckoning. Lord Belhaven was lost on the Lizard in 1721, the same day on which he sailed from Plymouth, England.

At this point two most vital discoveries making for advancement in Navigation were made. The rise of modern navigation may fairly be dated from the invention of the sextant by Hadley in 1731 and of the chronometer by Harrison in 1735.

The sextant is an instrument for the measurement of angular distances. As such it replaced the cross-staff and the astrolabe, than which it is far more convenient and accurate. The cross-staff required the observer to sight in two directions at once, while the sextant forms two images of the object or objects observed as near together as desired in a small telescope. The astrolabe was suspended and was supposed to be kept plumb by gravity, but the movement of the ship rendered accuracy impossible. Three observers were required to manipulate it. The sextant is easily handled by one observer, who, with practise, soon acquires great proficiency and accuracy in the measurement of angles although his position may be on the unsteady deck of a ship at sea.

The chronometer is a time piece like a watch in that it is actuated by a spring and depends upon a balance wheel for the measurement of time. It is however much larger and usually much more accurate than a watch; and it is mounted on gymbals so that it may by its own weight remain face up when its case is tipped.

In early times mariners used the compass as a rough sun-dial for the determination of time. Water-clocks and sand-clocks were employed for rough purposes of keeping time on board ship and it is curious to note that hour and half-hour sand glasses were used in the British navy until 1839. When watches were introduced in 1530 they were not accurate enough to supersede even the primitive devices then in use. The practical difficulty arose from their very irregular rates, owing to change in temperature and the motion of the ship. Harrison's great invention, which made possible the chronometer and greatly improved the watch, was the principle of compensating the balance wheel by the use of two metals with different coefficients of expansion together with a device by which the chronometer retains its motion while being wound.

Harrison was eager to try for the longitude prizes with the help of his new invention. He believed that his time-piece, if set and rated carefully before embarking, could be relied upon to keep Greenwich time for a voyage of several months with such accuracy that greatly improved longitude determinations at sea could be effected. In 1735 he was allowed to test one of his first watches on a voyage to Lisbon, with a result so satisfactory that he received a grant of 500 pounds to carry out further improvements. The official trial

*From *Popular Astronomy.*

journey to the West Indies was begun in November, 1761, with an improved chronometer, and during the whole voyage of five months the total error unallowed for was 1 min. 54.5 sec. or the equivalent of 18 miles in the latitude of Portsmouth, an amount well within the limit of 30 miles specified for the grand prize of the Longitude Commission.

Apparently Harrison had won the prize of nearly $100,000.00; but the invention of the sextant which had helped Harrison by facilitating the determination of local time, had been especially favorable to certain powerful competitors who hoped to gain the reward by measurement of lunar distances from stars. Much improved lunar tables had been submitted by Mayer in 1755. These were pronounced generally correct within a minute of arc; and Maskelyne, after a trial voyage to St. Helena in 1761, during which he determined longitudes within 90 miles or so, prepared a guide, issued in 1763, in which he asserted his belief that the lunar method would determine longitudes always within 60 miles on the equator and generally within 30 miles, if applied to careful observations. Encouraged by this progress, though the process involved was too laborious for seamen to undertake, the House of Commons withheld the prize from Harrison and left an open chance for a lunarian during four years from 1763.

In March, 1764, on another trial voyage to the West Indies, Harrison's watch made a record even better than before, running four months with an error not greater than ten miles in longitude. Accordingly in the following year he was awarded one-half of the prize of twenty thousand pounds; but at the same time, authority and funds were given for the publication of the Nautical Almanac, containing among other things tables of the Moon's distance from the Sun, when suitable, and from seven fixed stars at intervals of three hours. Apparently the longtitude commissioners were still on the fence.

The tables of lunar distances in the Nautical Almanac, together with Maskelyne's auxiliary tables facilitated greatly the lunar method for finding longitude. But steady progress toward the perfection of the chronometer maintained the superiority of the chronometer method of longitude determination, and soon after 1800 the longitude controversy may be considered to have been settled in favor of the accurate time-piece.

The marvellous accuracy of the modern chronometer —of even the cheaper chronometers used in the mercantile marine—is illustrated by the steamship Orelana sailing from London to Valparaiso. In a voyage of sixty-three days the mean accumulated error of her three chronometers was only 2.3 seconds of time, or one-half mile in longitude at the equator—and less in higher latitudes.

At the present time, since the Greenwich time can be sent out by wireless from shore stations, in the problem of longitude determination even less dependence need be placed on the chronometer, and the accuracy of such determinations is not necessarily appreciably different from that of latitudes.

Equipped with the compass and log, sextant, chronometer, lead, Nautical Almanac, and the *Requisite Tables* the navigator was ready to sail with comparative safety over long voyages early in the nineteenth century. The crying need was for more and better charts and for better knowledge of tides, winds and currents. The establishment of the Admiralty Hydrographic Office of Great Britain in 1795 marked a great step in advance in these directions. The first official catalog of the Admiralty, issued in 1830, listed 962 charts. And in 1832 official tide tables were issued also by the Admiralty. At present the navigator's charts cover all the important coasts and seas, with very full data of tides, winds and currents.

In the United States, marine chart work began in the Navy Department in 1837. From 1844 to 1861, the United States Observatory and Hydrographic Office under Lieutenant M. F. Maury devoted itself not only to astronomical and hydrographic work but also to important research in marine meteorology. This period is notable for the issuance of Maury's famous "Wind and Sailing Charts" and "Sailing Directions." It was Maury's wish that the Wind and Sailing Charts should be an exclusively American contribution to world Navigation. In 1866 the hydrographic and meteorological branches were disconnected from the Naval Observatory and given to the present Hydrographic Office, and in 1904 the work of marine meteorology was transferred to the Weather Bureau. The United States Hydrographic Office conducts marine surveys, collects information for nautical publications, and prepares manuals, charts, sailing directions and nautical tables for the use of navigators generally. In a single year it prints about four hundred thousand charts and many more pamphlets and bulletins. It sells about one hundred thousand charts and books to navigators each year. The United States Coast and Geodetic Survey prepares and distributes tide tables and also charts and pilots of our coasts.

In recent times the great development of modern ships in both size and speed has increased enormously the demands on those who command and navigate them and has led to careful study and improvement of methods in Navigation. Simplified procedure, better tables, and a higher standard of preparation of the navigator have been realized. On the instrumental side the sextant and chronometer have been carried toward perfection, the sounding machine much improved and the gyro-compass introduced. The original model of one of the best modern types of magnetic compass was patented by Lord Kelvin in 1876. The gyro-compass is used side by side with the magnetic compass but cannot be said to have superseded it. The rotary or patent log came into general use about 1836, but was introduced in the form usually employed at present in 1878. It records the revolutions of a small screw towed by the ship and, like a speedometer, registers the speed of the ship and the distance run at any instant.

The important features of modern practice in Navigation may be brought out by a brief account of methods now employed. In planning out in advance a long ocean voyage the navigator would first lay down on a chart the track from port to port. It would be his object to adopt the shortest route available, taking into account currents, winds, ice and other undesirable features of high latitudes, as well as specified lanes of traffic, and the intervention of land. Since the great circle route is always shorter than any other, especially between ports far apart in longitude and in high latitudes of the same name, a great circle chart is often used, for on such charts a great circle appears as a straight line. But since the track will be transferred finally from the great circle chart to one on a Mercator's projection, which is more convenient for purposes of navigation, the course may be entered in the beginning on a Mercator's chart using the method proposed by Airy for drawing approximate great circles. On a Mercator's chart the track followed by a ship steering a continuous course is a straight line (technically known as a rhumb line), and since ships rarely, if ever, steer on great circles and, instead, follow a series of rhumb lines like chords of the great circle track, differing successively one or two degrees in direction, it is desirable to use a Mercator's chart upon which each such course appears as a straight line.

Having thus planned the most advantageous general track to follow, three methods are used to determine the position of the ship at any time during the voyage: these are (1) projecting the track on charts; (2) simple trigonometrical calculations based upon the course steered and distance run as shown by compass and log; and (3) astronomical observations with sextant and azimuth circle.

Of these the first is generally least trustworthy owing to the unavoidable small scale of the charts. But when a ship approaches or leaves a coast, chart sailing becomes obligatory and large scale charts are available for the purpose.

On leaving harbor, the so-called point of departure is found, possibly by astronomical observation but preferably by sighting on objects on shore as mapped on the chart of the port. In hazy weather especially, a continuous line of soundings at fairly even distances apart affords an additional control of one's position, and for this purpose the sounding machines invented by Lord Kelvin, permitting satisfactory soundings at speed of 15 or 16 knots, are most useful.

While in sight of land the course can be followed best by land sights and soundings, a method of navigation usually referred to as piloting. Before losing sight of land the longitude and latitude of the last well-determined position found by methods of piloting is taken from the coast chart and transferred to the ocean or small scale chart and is considered as the point of departure.

The point of departure is the starting point of the ocean voyage; and from that point the course and distance are laid down, being rectified whenever astronomical observations are available. More accurately, though less vividly than on the chart, the changes in longitude and latitude involved in each change of course are computed by plane trigonometry, using so-called traverse tables for the solution of the right-angled triangle involved. Such a method of keeping account of a ship's position on the basis of the course as indicated by the compass and the distance as indicated by the log, allowing for wind, current, and tide, is called dead reckoning. As bearing upon the accuracy of the log, it is interesting to note that some authorities, in the case of steam vessels, consider that the revolutions of the ship's propeller, taking into account the condition of the ship's bottom, afford the best means of estimating speed.

Astronomical reckoning affords the most accurate means of ascertaining positions at sea, dead reckoning being carried along partly as a check but also to be relied on when weather does not permit observations of the heavenly bodies.

Navigators will generally prefer to determine position from observation of the Sun, measuring the altitude of that body above the sea horizon. But similar observations of the planets and brighter stars in twilight, when the horizon is still well defined, afford even better determinations of positions at sea. In such a case the careful navigator, by observing for latitude two stars, one north and one south of the zenith, and for longitude two stars, one east and one west of the zenith can depend on a good result, especially if the stars in each pair are about at the same altitude and not too low in the sky. Since the Moon also may be used when occasion arises, it is evident that the navigator seldom needs to go long without a good fix or determination of position.

The chief astronomical observations made at sea are those for ascertaining (1) latitude, (2) time and longitude, (3) compass error, and (4) latitude and longitude simultaneously.

The general aim among navigators, excepting perhaps the more progressive, is to observe with a sextant the altitude of the Sun in the morning when that body is nearly above the east point, to determine local time and longitude. In the computation of local time it is necessary to adopt a latitude obtained by dead reckoning, but if the Sun is well placed errors in the assumed latitude will introduce relatively small errors in the resulting ship's time. The longitude is obtained by taking the difference between the ship's time and the corresponding Greenwich time recorded by the ship's chronometers. This longitude is carried forward to the following noon by dead reckoning. The latitude at noon is determined by measuring the altitude of the sun on or very near the meridian. Another time sight may be made before sunset. Or if stars are used at twilight one is observed east or west for longitude and another north or south for latitude. A longitude by dead reckoning may be used first to derive the latitude and then with the observed latitude the longitude may be obtained, though in unfavorable cases more trials may be necessary.

The newer methods, which are rapidly superseding other modes of ascertaining a ship's position, are based upon the use of the Sumner line of position. In these methods each sextant altitude of a heavenly body is used to determine all it ever can actually give, a line on the sea on which the ship must be situated. Such a line, though in practice nearly always sensibly straight, is in reality an arc of a small circle on the earth's surface having its center immediately under the celestial object observed with a radius equal to the zenith distance of that object. The Sumner line may be defined by two points, in which case two longitudes or two latitudes are assumed or derived by dead reckoning and the other co-ordinate computed. Or the line may be defined by one point derived in this or a similar way together with the direction of the line, which will be at right angles to the direction of the body observed, at the time of the observation. If the Sumner point, thus used in defining the Sumner line, is to be adopted as a point of departure, it is important that it should be a probable position, taking advantage of the evidence furnished by dead reckoning. In the Marc St. Hilaire method, which is generally preferred, this point is the intersection of the Sumner line with the vertical line of the celestial object observed, assuming for the observer the position obtained by dead reckoning.

Some help toward an understanding of Sumner's method will be found in an account of its discovery. Sumner sailed from Charleston, South Carolina, in November, 1837, bound for Greenock, England. After passing longitude 21° W., about 800 miles west of London, no observations could be made until soundings had indicated that the ship was near land. About midnight of December 17, dead reckoning indicated that the ship was within forty miles of Tuskar light off the Irish coast opposite Wales, and the ship stood off the supposed shore to await developments. About ten o'clock the next morning an altitude of the sun was observed and the chronometer time noted, but, having run so far by dead reckoning, it was plain that the knowledge of the latitude was not sufficiently reliable to afford a determination of longitude. Nevertheless Sumner computed his longitude, using the latitude by dead reckoning, and got a position 15′ east of that by dead reckoning. Then in order to determine how far

(Continued on page 378)

Photo by Com. Pub. Information

Observer receiving instructions from an officer

Photo by Com. Pub. Information

A type of long-focus camera much used

Map Making from the Sky

Camera Now Most Important Means of Making War Maps

TODAY, thanks to the accuracy of the military maps, the enemy can hold few secrets in reference to positions of artillery, troops, trenches or fortifications. The military airplane and the camera are responsible for this change. In no other war has the camera played as important a part. In the present it has become vital. In the early days of the war, aviator observers were instructed to make rough maps and sketches while over the enemy lines, but this crude work was quickly abolished when it was found that by simply pressing a camera button at the right time absolutely accurate maps to the smallest details could be obtained.

The making of military maps in other wars, previous to the present one, was often a long and tedious process at the best and when of enemy positions a most difficult and frequently more or less inaccurate one as such maps were necessarily based more or less on information furnished by spies and prisoners.

While the former of course made every effort to be accurate in the information furnished the map makers their opportunities for accurate observation and the taking of notes was almost always limited, besides being confined to comparatively small sections, while data extracted from prisoners, by inquisitorial methods, was much more likely than not to be intentionally misleading. Many a battle which might easily have been won, other things being equal, has been lost solely because of a lack of accurate information of enemy positions.

In the present war all this has been absolutely changed and now-a-days the enemy can hold few secrets in reference to positions of artillery, troops, trenches or fortifications as two absolutely new additions to modern warfare have utterly abolished the difficulties in the way and changed the old time methods of making military maps, and transformed these vitally necessary adjuncts to successful advance movements of troops against the enemy into positively accurate records on which fullest dependence can be placed for a time at least.

The military airplane and the camera in combination, both for the first time used in the present war, are the new methods which have put the stamp of accuracy on the war maps of the armies today and taken them quite out of the realms of guess work.

During the past few years every one has become quite familiar with the daring and successful fighting of the flying corps of the allied armies but scant mention however has been made of some of the duties of the military aviators, and among the most interesting and vitally important of these is the expert use of the camera in map making over enemy lines.

Along the Frnech front to call the airmen the eyes of the army is a very common metaphor.

At the beginning of the war they did much observation for the artillery besides playing a leading part in general reconnaissance, but actual map making was still carried on along the same old lines as the camera did not immediately come into its own, the photographer and the birdmen not having been joined up.

The importance of the aircraft for observation purposes was so quickly demonstrated to military men, however, that it was not long before they began to think of some simple and accurate methods whereby these observations could be transformed from mental pictures of the aviators to permanent accurate records in black and white.

Photo by Com. Pub. Information

An airman's photograph of part of the Hindenburg line, showing acres of barbed wire in front of it, and reserves and communicating trenches in the rear

At first the observers in the airplanes were instructed to make careful sketches on paper of what they saw, and this served for a time until some one suggested that the camera would be a much better method. So it was tried at first with only fairly satisfactory results; but as special apparatus was devised for this work, and the operators became more experienced the wonderful possibilities of this method of camera map making finally fully dawned upon the military commanders.

Where hundreds of copies of every view taken are developed and printed

So fully have armies come to depend upon their aircraft for observations that without them they would feel practically blind, and without their camera airmen they would not be the all seeing eyes that they are. Thus as the airmen have become the eyes of the land forces, so the camera has become the eyes of the airmen providing that part of his vision which is most penetrating and accurate.

Few civilians back home and away from the battle-front, even those who have become more or less familiar with the camera by their amateur or professional use of it, have any idea of what wonderful piece of accurate map making work a series of photographs made from the air really is. Not one but hundreds of photographs often go to make it, and these are so carefully taken, and so cunningly fitted together, that a complete photographic map with infinite detail is finally obtained. There is no rest for the aerial photographers and no end to their work. Every day on which there is a reasonable visibility they must fly into the face of danger to discover new secrets with their cameras. The danger is of a particularly unpleasant kind, because throughout the operation they are within effective range of the anti-aircraft guns which are the flying man's most inveterate if not his most deadly enemy. To take a series of photographs of an enemy position in a caldron of bursting shrapnel needs a special coolness and nerve.

It is interesting to gain a mental picture of how they go about their work. It is a fine clear day, an ideal one for the photographers of the air to go ahead with their work.

A machine is run out from the sheds, and pilot and observer mount to their places. It is not a fast airplane, as speed is not counted, but each man is armed with a machine gun and attack from the air will be met with stout and efficient resistance. Attack from the ground cannot however be answered. It can only be evaded by manoeuvre.

Through a hole in the fuselage, or body of the machine, a camera points earthward, capable of reproducing a considerable area on each plate exposed. The device with which the snapshots are taken is as simple as it is ingenious, and it is almost "fool proof." It is the duty of the observer to take the photographs; of the pilot to pass over the exact ground detailed for observation.

While the aviators are making their airplane ready other men are carefully examining the camera to be used on the trip for any possible defects, and putting on board the machine the plates and all other necessary adjuncts.

Then a photographic officer shows the observer photographer on a rough sketch the area to be photographed.

When all is ready and instructions fully given and understood the machine takes the air.

In half an hour or so the machine has crossed the

enemy lines at a height of little more than 4,000 feet. Far above are small, fast scouts ready to attack any aerial enemy that may attempt to interfere with the work below. From the first anti-aircraft guns are uncomfortably attentive, but the bursts can at this stage be defeated by climbing, diving or swerving movements.

It is when the actual objective of photographic attack has been reached that the real difficulties and dangers come. Further dodging and diving are no longer practical, since an accurate pictorial record can only be obtained by steady flying. The airplane must be as level as possible when a snapshot is taken. Yet the enemy knows the purpose of the invader and chooses this moment to make his utmost effort to destroy him. The shell bursts are thicker than ever. The range has been nicely judged; the bursts are well aimed.

In the midst of them the two must do their work as steadily and quietly as if the air were still. Up and down, over the narrow section of ground whose secret must be won, the pilot steers, for the most part an even course. Shells burst closely round them, on this side and that, beneath and above. At moments the pilot is forced to swerve, but he must quickly get level and resume his ordered course.

Meanwhile the observer studies intently the pitted earth below, which would appear to the uninitiated as indefinite as a huge ploughed field. But his practiced eye picks out its essential features, and regardless of the shells, he presses his lever at carefully-timed intervals. At last the deed is done—just as a shell bursts close under their tail and tosses them upward as a wave might lift a cork. Fortunately the damage is slight.

"Finished?" asks the pilot through his telephone.

"Finished," says the observer.

And they swing for home with an inevitable sense of relief.

It is all in the day's work—a very ordinary job. But even the airman's most ordinary job is out of the common as a risky experience. As for the knowledge obtained, it may prove of vital importance. The camera is more than an eye: It is a weapon. And the hand that controls it must be as purposeful and steady as if it held a rifle.

Of course the aviator photographers must be experts at their work to obtain the desired results. They must know, among other things, accurately how much atmospheric haze their lens will penetrate. This knowledge will tell them whether to expose their plates at a height of two miles, or to descend through great danger to the half mile level. There are also numberless other fine points of photography of a similar nature with which they must be familiar.

When the map making airmen return after successfully encountering many battle perils without practically a fighting chance their first duty before leaving their machine is to hand the exposed plates to a photographic officer who is waiting, and whose duty it is to see that the plates are properly guarded and conveyed as quickly as possible to the dark room in the nearby military laboratory where the plates are most carefully developed by expert photographers. If the negatives turn out well prints are made and the map making or piecing of them together begins.

Should the negatives for any reason turn out badly then the aviators are informed of the fact, and the dangerous work has to be done all over.

Finally, when the photographic maps are completed they are shown to the aviators who made the negatives, who are required to go over them carefully and to check up from memory any possible error in putting the prints together. At times even another flight is required for verification but as a rule this is not necessary.

Frequently when speed is demanded in the making of a photographic map of a certain section, so complete is the photographic organization that such a map is in the hands of the officers directing the movement of troops and the operation of the big guns within a half hour after the aviator returns with his precious negatives from his flight.

British Official Photo

Inspecting cameras preparatory to a reconnaissance

British Official Photo

Pilots and observers locating German position

Salvage of Ships in Great Britain

THE British salvage fleet, which now includes a considerable number of vessels operating in home waters, in the Mediterranean, and in more distant seas, consists mainly of converted gunboats, although little but the old composite hulls, which are particularly well suited to salvage operations, remain of the old vessels when equipped for their new mission. The propelling machinery in the latest type of vessels is of the reciprocating type, giving about 1,000 h.p., and the engine room contains an electrical installation as well as an air compressing plant for supplying power to the electrical pumps and pneumatic tools. A two-cylinder vertical steam engine drives an alternator having an output of 187 kw., and a lighting dynamo is included.

PUMPING PLANT.

The powerful pumping installation comprises 8-in. and 12-in. steam pumps, the latter having a capacity of 800 tons per hour, and being the largest size employed. Experience has indicated that larger pumps are apt to be unwieldy, while the size is also regulated by the fact that in cases where the salvage vessel is unable from weather or tidal conditions to remain alongside the wreck, self-contained pumping sets have to be put aboard the vessel on which operations are in progress. As it is not always possible, owing to the character of the damage, to supply steam to work these pumps the salvage equipment includes 12-in. and 8-in. oil-driven motor-pumps, which are self-contained units. The larger motor-pumps have a similar capacity to the steam sets. Both these types have, however, a somewhat limited lift, and for work requiring a high lift excellent service has been rendered by submersible electrically operated pumps. These are made for salvage work in the 4-in. and 8-in. sizes; the latter has a capacity of 350 tons an hour at 75 ft., and 500 tons at free discharge, while the 4-in. pump has a capacity of 100 tons an hour at the maximum lift, and 160 tons at free discharge. Under normal conditions current for working the pump is supplied from the ship's generating plant, but portable generating plant is also available.

The air compressor in the ship visited, and it may be noted that all the foregoing details apply to the equipment of this vessel, has a capacity of 250 cu. ft. of air a minute compressed to 110 lb. The ship also carries a line-throwing gun for effecting communication with the wreck, and an oxy-acetylene plant for cutting out damaged plates and other work. In view of the character of the equipment carried, a workshop containing the necessary machine tools is provided. Although the capacity of the pumping plant on any single vessel is somewhat limited, large reserve stocks are maintained at all the depot ports and can be drawn upon at the shortest notice, and in one recent case it was possible to have in operation pumping capacity representing a discharge of 14,000 tons of water an hour.

CHARACTER OF THE WORK.

An idea of the extent and character of the work carried out by the Salvage Fleet was obtained by the facilities granted for inspection of a number of vessels which had been salved by the ships attached to the port visited and which included liners, hospital ships, oil tankers, large cargo steamers, as well as the ordinary ocean tramp. It has to be borne in mind that this is but one centre of activity and that operations of the same kind are in progress at all the great ship-repairing ports of the United Kingdom. One of the reaches of the approach channel of the port visited is the hospital ward of the Salvage Service, and the ships beached or moored are in various stages of convalescence. Some have already had their wounds dressed and are merely awaiting orders to be returned to active service; alongside others the Red Cross Service of the sea is in attendance, and all that skill and experience can suggest is being done to enable these vessels to leave the sick bay at the earliest possible moment. Pumping plant is in constant operation and divers are at work day in and day out ascertaining the extent and character of the wounds and taking measurements for the purpose of grafting on the skin of the ship one of the standard wooden patches which the Admiralty Salvage Service has devised for the quick temporary repair of vessels.

The plating destroyed by torpedo explosion may extend over a length of 45 ft. and a depth of 25 ft., and it is the task of the diver to obtain a mould of the damage. An arrangement of battens and thumbscrews enables him to test the accuracy of the mould taken, and one special advantage is that the whole of the drilling necessary for the attachment of the patch can be done inside the ship, so that the diver has only to fit on the nuts from the outside. In view of the limited time in which divers can work alongside a wreck this method of temporary repair has materially shortened the period during which vessels remain in the hands of the Salvage Section before proceeding to their repairing port to undergo complete overhaul. In other instances a cofferdam is fitted to the ship's side over the damaged section and it is then possible to carry out permanent repairs in the dry.—*London Times Engineering Supplement.*

Muck Formation in the Klondike

MR. J. B. TYRRELL (Trans. Roy. Soc. Canada, vol. xi., p. 39, 1917) concludes that the deep vegetable deposits known as "muck," resting on permanently frozen gravels in the Klondike district, began to accumulate at the very opening of the Glacial epoch. The supply of gravel through river action was then cut off, and conditions were established which have lasted down to the present day. The permanently frozen substratum furnished an impervious foundation, on which sufficient water gathered in spring to allow of the growth of Sphagnum and Hypnum, while the streams from the hill-slopes washed down into the flats representatives of the forest flora of the district.—*Nature.*

The Movements of Oil and Gas Through Rocks*

Geological Factors That Influence the Phenomena

By Victor Ziegler

ONE of the most interesting problems confronting the student of oil geology is the migration of oil and its possible causes. That such migration is quite prevalent and perhaps a universal characteristic of all oil, is scarcely to be doubted. The widespread occurrence of oil and gas seeps and springs, and of occasional gushers and flowing wells, bears mute evidence of the truth of this fact. The explanation of the "why" and the "wherefore" of migration is by no means simple. There are a great many possible causes of migration, each one of which has had its influence. These depend upon local conditions and, hence, may be more or less pronounced or may vary in intensity and importance from field to field. For this reason we find a lack of agreement among geologists as to the relative importance of these various causes. Each one champions, as is natural, the particular cause most active in the fields under his direct observation. The writer has attempted to summarize the divergent views expressed in the all too meager literature on this subject, and to differentiate as far as possible the effects of each active factor.

The problems of oil movements are intimately connected with the problems of its origin. While there is as yet no general agreement among geologists on the question of oil origin, the organic theories may be considered to be at least tentatively established. It is outside of the scope of this paper to discuss such theories. The writer personally feels convinced that oil is derived from organic material, such as plant and animal remains which were buried in the finer sediments, the muds, clays, and oozes at the time of their deposition. Because of the fine and, hence, dense character of these sediments, of the presence of salt water, of generally undisturbed and quiet conditions at the place of deposition, the organic remains were protected from rapid decomposition, and suffered only a sort of selective putrefaction. Upon deeper burial by the increasing load of sediments, there took place decomposition and distillation of the organic remains which resulted in the formation of oil. This change was in part due simply to the increasing pressure and temperature, and in part due to the action of bacteria. Thus, the first fundamental premise of this paper is:

All important oil accumulations are the result of the chemical or bacterial alteration of organic remains.

In probably 95 per cent. of all oil pools, sands and sandstones form the reservoir rocks. They are the oil producers but not the oil formers. The writer is convinced that oil is not indigenous to the great majority of oil sands. The coarse character of most oil sands, their original porosity, the disturbed conditions at the site of their deposition as proved by their cross-bedding and by their lenticular streaking with gravel and the virtual absence of fossils, all prove that sands are unsuitable for the preservation of perishable organic remains. This is further borne out by the absence of important commercial accumulations of oil or gas in the very thick sandstone and conglomerate series, as well as the absence of oil in certain sandstones that are characterized by an abundance of fossils, such as brachiopod and mollusc casts. Thus, the second fundamental premise of this paper is:

By far the greater part of oil is formed in the fine-grained sediments, those that ultimately form shales and, to a lesser extent, limestones.

If we grant the truth of these two fundamental premises, the questions concerning the movements or flow of oil and gas through rocks can be clearly differentiated into two separate problems. Thus, it becomes necessary to answer the following two questions:

First, what causes the removal of oil and gas from the oil-forming shale, and its segregation in the sands and sandstones?

Second, what causes the oil that is disseminated through the sands, throughout their whole extent, to be concentrated into commercially valuable pools?

In order to answer these questions satisfactorily it will be necessary to summarize briefly all possible causes of oil and gas migration. The following table shows these classified under four main headings:

A CLASSIFICATION OF CAUSES OF OIL MIGRATION.

A. Gravitative causes.
- I. Rock pressure.
  - 1. Original.
  - 2. Secondary.
- II. Differences in specific gravities.
- III. Water pressure.
  - 1. Hydrostatic.
  - 2. Hydrodynamic.

B. Molecular causes.
- I. Surface tension.
- II. Adsorption.
- III. Adhesion.

C. Intratelluric causes.
- I. Earth movements.
- II. Heat gradient.

D. Chemical causes.
- I. Deposition of cement.
- II. Formation of gas—gas pressure.
- III. Heat due to reaction and polymerization.

GRAVITATIVE CAUSES (1, 3, 5, 8).

The gravitative causes depend directly upon the action of gravity for their effect. These include rock pressure, which may be defined as the pressure at any point under the surface of the earth due to the weight of the overlying rocks. Rock pressure can only be effective as a cause of motion when the rock itself is unable to sustain it and transmits this pressure directly to any liquid or gas held in its pores. Whenever burial is deep enough so that no openings can exist in the rock, the rock is said to be in its zone of flow. Rock pressure increases regularly with depth of burial. The amount of pressure and hence depth under the surface necessary to place a rock in this zone depends on its crushing strength, and consequently, varies for the different kinds of rocks. I wish to distinguish between two different kinds of rock pressures as original and secondary respectively. Original rock pressure is that due to the weight of the sediments at the time of their deposition. It results, in the main, in the compacting of the sediments into rock. Secondary rock pressure is due to the burial of the sedimentary rocks in the zone of flowage subsequent to the consolidation of the sediments.

Another gravitative cause of oil migration is to be found in the differences of the specific gravities of oil and water. Because of their immiscibility, the tendency will be for the oil to rise to the top of the water surface. The higher the porosity of any reservoir and the greater the proportion of large and connected openings, the freer the flow of liquids takes place. Oils of high-degree gravity and low viscosity are the most fluid and, consequently, are able to penetrate comparatively fine pores. Any increase of temperature is helpful because it reduces viscosity. Oils of low gravity may approximate the weight of water so closely as to afford no opportunity for a gravitative separation of this nature. In reservoirs with low porosity and in those with fine pores, the friction may be so great as to prevent all movement due to this cause.

The great majority of reservoir rocks are saturated with water which in itself may cause oil movements (1). Thus, the water is under pressure which at any point under its surface is equivalent to the weight of the column of water above. Pressure of this sort is equal in all directions and is known as hydrostatic pressure. It is really responsible for the rise of drops of oil to the water surface. Water tends to seek its own level. The effective pressure on the water which tends to equalize its upper surface is "head." Both "head" and hydrostatic pressure are pressures possessed by water by virtue of its position or location.

Water may also flow in perceptible currents through the reservoir rocks. It will exert pressure which, in part at least, is due to its momentum. Such pressure, which results from the motion of water currents, is "hydrodynamic." Munn (3 and 4), who was apparently the first to recognize the importance of currents in localizing oil pools, applied the term "hydraulic" to these effects.

MOLECULAR CAUSES (7, 8, 9, 2, 11, 12).

Three possible causes of oil migration owe their existence to molecular forces. The effects of two of these, adsorption and adhesion, are not clearly understood, and are probably of no great importance. Their effects are so similar that they cannot be clearly distinguished. Adsorption is a term applied to such phenomena as the condensation and retention of a gas on the surface of a solid, or the concentration of a dissolved substance on the surface of a solid or on colloidal particles suspended in the solution. All chemical reactions which are primarily the result of the interaction of films and which are apparently limited by molecular dimensions are adsorption phenomena. They are in part chemical, in part physical, and appear to be concerned only with reactions between substances or films that are molecularized. A practical illustration will make clear its effect. An emulsion of oil and water in which the individual oil drops approach molecular size would quite likely be formed during the original distillation of the parent organic matter. Since this is in contact with different kinds of rocks and, consequently, different minerals, there may be a selective effect which results in the concentration of the oil on the surfaces of certain minerals. Thus, adsorption of this nature would require a diffusion of the oil particles through the water.

How important a part adhesion—that is the attraction of unlike molecules for each other—plays in this action is difficult to state. That certain minerals, especially metallic and basic ones, exert a stronger attraction towards oil than towards water, is proven by the success of oil flotation methods in ore dressing. The distinction, while not absolute, appears to be as follows:

Selective action of this sort that takes place in solutions is attributable to "adsorption." A similar selective action in coarse suspensions is the result of adhesion. In both cases the causive forces are purely molecular. In the first case, concentration is effected by molecular diffusion; in the second, by distinct currents.

While there may be a selective attraction of the basic rocks or minerals for oil, the writer is of the belief that the effect is negligible as an active cause of oil movement. Adsorption and adhesion may have some slight importance as conditioning factors in such migration.

The most important of the molecular causes of oil migration is the differences in the surface tension or capillary pressure of oil and water. Its effects were first clearly enunciated by Washburne (7). The rise of liquids up capillary tubes and into sponges, and the rounding of liquids into spherical drops, are familiar examples of surface tension phenomena. They are the result of the combined action of cohesion and adhesion. Thus, water rises in glass tubes with openings microscopic in size against gravity, because the attraction of the glass for the water is greater than the attraction of water for water. In other words, adhesion is the greater force. Other conditions being equal, the surface tension can be determined by observing the height to which the fluid rises in a capillary tube.

The surface tension of water at ordinary temperatures is about three times that of crude oil. Water, therefore, exerts by far the greater pressure in entering capillary openings. The effect of this difference in pressure will be a selective action. Thus, the water will enter the openings and pores of smallest size, while the oil will occupy the openings of larger diameter. A few simple experiments furnish ideal illustrations of this phenomenon. Thus, a small block of diatomaceous earth (or chalk) suspended in an emulsion of crude oil and water of known composition, which is kept in an agitated condition to prevent gravitative separation, will absorb the water much more readily, so that after its removal and the settling of the emulsion, the proportion of oil will have greatly increased. Two glass plates wedged apart on one end so as to produce a capillary opening of sheet-like shape between them, and placed in a similar emulsion of water and oil, will illustrate the same principle. The emulsion will rise at once in the capillary sheet and separate; the water occupying the narrower portion, the oil, the wider. Both simple experiments clearly illustrate the fact that any emulsion of water and oil will tend to separate. The water, because of its superior surface tension, will occupy the openings of smaller size and will force the oil into the larger openings and pores.

Surface tension and the resulting capillary pressure are independent of direction on the whole, but in general are more effective vertically upward. This is due to two factors—the heat gradient and the increase of pressure with depth. The effect of increase in temperature is to decrease surface tension. The surface tension of water decreases at a more rapid rate than

*From *Economic Geology*. The figures in the text refer to articles in the appended partial bibliography, which deal either directly or indirectly with the features discussed.

that of crude oil, so that after comparatively slight burial the surface tension of the two are virtually the same and this cause of motion becomes ineffective.

The increase of pressure with depth tends to decrease the effective openings and pores in the rocks and will eventually close them entirely. The resistance offered to a liquid that moves through capillary tubes increases with decrease in size, and, therefore, with depth of burial. Surface tension is probably most effective within three thousand feet of the earth's surface.

INTRATELLURIC CAUSES.

Both earth movements and heat gradient are probably minor causes of oil movements. Folding and faulting, as well as the most persistent oscillatory movements, such as the body tides, must have stimulated migration to some extent. In general, such movements would be similar to the kneading to which a baker subjects dough, and would result in a squeezing out of the liquids towards the earth's surface. Heat gradient would have a similar effect. An increase of heat would stimulate circulation. In the case of oil, it would result not only in an expansion of volume but also in the production of gases. In general, the circulation set up would be vertically upwards. Neither earth movements nor heat gradient are as effective in causing oil migration as the gravitative causes or surface tension.

CHEMICAL CAUSES (8, 10, 5).

The localization of oil pools in a reservoir rock may be occasionally accomplished by cementation (8). Thus, the gradual deposition of cement in the interstices between the grains of sandstone may force the oil to move through the rock, and may eventually collect it in an oil pool. Some oil pools occupy porous lenses in thicker sandstone beds. They appear to be pockets of oil completely surrounded by well-cemented and virtually impervious sand, and may well have been formed in this way.

It is logical to assume that the oil under the earth's surface, subjected to different temperatures and pressures, tends to polymerize and so produce new oils and gases. This tendency should increase with depth of burial, and is apparently borne out by the fact that oils show an increase in gravity with depth, and also that the proportion of gas increases with depth of reservoir. The new gases so produced may be, and in most cases are, actually above their critical temperatures and pressures. They are not true gases, therefore, but in that state of matter where the true distinction between gas and liquid disappears. These lighter hydrocarbons may be under tremendous pressure due to their tendency to expand. Relief may be afforded by the movement of the oil. This pressure we know as gas pressure. It is checked under the earth's surface by the rock pressure and by the resistance offered to the flow of oil. High gas pressure is always favorable to production, as it promotes the rapid flow of oil. Gushers and flowing wells are characteristic of fields with high gas pressure.

In the polymerization of oil and in other chemical reactions that may take place in it, heat is liberated. This will of necessity augment the effect of the increase in temperature due to heat gradient.

All factors discussed separately probably played a part in causing oil migration. To some extent, at least, their effects can be differentiated. According to the fundamental premises of this paper, the oil is not indigenous to the reservoirs from which it is now produced. Shales are considered the real home of the oil. The causes of oil motion must be differentiated, therefore, into two classes—first, selective or segregative causes, those responsible for the movement of the oil and gas from the oil-forming shale into the reservoir rocks, and, second, concentrative causes, those which result in the concentration of the oil into commercial pools. These are shown in tabulated form:

CAUSES OF OIL MIGRATION, CLASSIFIED AS TO EFFECTS.

A. Selective or segregative causes.
- I. Essential.
  - 1. Rock pressure.
  - 2. Surface tension.
- II. Contributory.
  - 1. Earth movements.

B. Concentrative causes.
- I. Essential.
  - 1. Differences in specific gravities.
  - 2. Water pressure.
    - (*a*) Hydrostatic.
    - (*b*) Hydrodynamic.
  - 3. Cementation.
  - 4. Gas pressure.
- II. Contributory.
  - 1. Heat gradient.
  - 2. Earth movements.
  - 3. Heat due to reaction and polymerization.
  - 4. Adsorption and adhesion.

The collection of the oil and gas in the reservoir rocks may be conceived of as a sort of "selective segregation" or "primary concentration" (8). It is effected chiefly by rock pressure and by surface tension aided and stimulated in a very minor way by earth movements. The original sediments which consist in greater part of muds with minor layers of sand or, perhaps, porous limestone, suffer considerable compacting at the time of their consolidation into rock. The muds especially are subject to a considerable shrinkage of volume. This decrease of volume is mainly the result of rock pressure. The sands and limestones offer greater resistance to pressure and cannot be compacted to the same degree. Their pores will hence remain open and serve as reservoirs for the liquid materials squeezed from the clays and muds. Capillary pressure also plays a rôle and probably the most important in effecting a primary concentration of oil and gas in the reservoir rocks. Thus, in the progress of time, the oil and gas produced in the shales from the organic matter buried in them will be driven out by water because of its greater capillary pressure, and will be forced into the rock with larger pores—the reservoir.

The greater the depth of burial, the more important the effect of rock pressure. The "original" rock pressure, *i. e.*, the pressure exerted at the time of compacting the sediments into rock, is probably most effective. This is active at the time of most rapid formation of oil from the recently buried organic matter. At this time the amount of water in the sediments is also greater than in any subsequent period. This, undoubtedly, aids in the rapid removal of any oil produced and its segregation in the more resistant and porous rocks.

Secondary rock pressure is that to which the sediments are subjected after they have been consolidated into rock and are buried in the zone of flow. The same processes will of necessity still be active, and may be quite important in those cases where high pressure and perhaps heat are required to complete the distillation of residual organic matter. On the whole, however, the writer is of the belief that most oils are formed near the surface, at low temperatures, and previous to the consolidation of the sediment into rock.

Rock pressure and capillary pressure are chiefly important in collecting oil and gas in reservoir rocks. Both will be disseminated through the entire reservoir. Only under very exceptional conditions can these two forces alone cause a concentration of oil and gas in commercial quantities. Oil pools in fissured shales and limestones may owe their existence mainly to such concentration.

The concentration of oil and gas disseminated through the reservoir into commercial pools is the result of water pressure and the differences in the specific gravities of gas, oil, and water, and, to a lesser extent, of gas pressure. Cementation may be an effective localizing cause under exceptional conditions. The effect of heat, earth movements, and adhesion or adsorption are so slight as to be contributory only. In the great majority of cases the concentration of oil and gas into commercial pools is the result of the difference in the specific gravities of oil and gas and water and of the movements of the underground water. As a result, oil and gas rise to the top of the water surface, and, where currents of underground water exist, are driven ahead of the water surface through the reservoir rocks. Wherever there are suitable structural conditions, an accumulation of commercial quantities of oil and gas may take place. The term "trap" is frequently applied to such a structure.

Gas pressure and water pressure are the most important causes of flowing wells and gushers, with one or the other dominant, depending upon local conditions.

There are a number of conditioning factors upon which the movements of oil are dependent (9). These are in part due to the characteristics of the reservoir, in part due to the oil, and in part due to local geological conditions. They are shown in tabulated form.

CONDITIONING FACTORS OF OIL MIGRATION.

A. Lithological character of the reservoir.
- 1. Degree of porosity.
- 2. Size and continuity of pore space.
- 3. Degree of saturation by water.
- 4. Proportion of induced to original openings.
- 5. Composition of reservoir as determining relative adhesion.
- 6. Effectiveness of cementation.

B. Physical and chemical character of oil.
- 1. Gravity.
- 2. Viscosity.
- 3. Proportion of gas.

C. Geological factors.
- 1. Structure.
- 2. Character of enclosing beds.
- 3. Local heat gradient.
- 4. Composition of ground water.
- 5. Depth of burial.
- 6. Geological history.

The characteristics of the reservoir rock are quite important in determining the relative ease of flow. Ready flow is favored by:

1. High effective porosity.
2. Large and continuous openings or pores.
3. High proportion of induced openings, such as fractures, joints, solution fissures.
4. Presence of water under pressure.
5. Cementation effective enough to hold and support the sand upon removal of oil.

The characteristics of oil also condition its movements. Ready flow is favored by:

1. High degree gravity.
2. Low viscosity.
3. High proportion of gas.

The greater the difference in the specific gravity of oil and water, the more effective gravitative separation will be. The lower the viscosity of the oil, the less the resistance that is offered to movements through the pores of rock.

A number of geological factors influence flow. Thus, steep dips flavor flow. Unconformities of the angular type are favorable to migration because of the more rapid concentration of oil from the lower series into the unconformable one above, due to the greater ease of travel along beds than across them. Certain sands are so friable that large quantities of sand are ejected from the wells. Oil flow is favored in these by the presence of strong resistant enclosing beds above and below the reservoir. Locally high heat gradient has the double effect of lowering the surface tension and decreasing the viscosity of oil. On the whole the effect will be to stimulate circulation. The presence of sulphated ground waters is obnoxious because it results in the production of sulphur compounds in the oil and increases its specific gravity and viscosity. The latter two render the oil less mobile. Depth of burial determines temperature and pressure on the oil, the effect of both of which has already been discussed. The past geological history of an oil field often gives us an explanation of peculiar localization of oil pools. Frequent oscillations in elevation of a district result in changes in the water level and must of necessity stimulate oil movements.

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Fluorides as Timber Preservatives.

EXPERIENCE in the Austrian Government Telegraph Department has shown that zinc fluoride is a good preservative for telegraph poles. A partial application is effective if complete impregnation of the wood is not desired.—*Chem. Zeit.*

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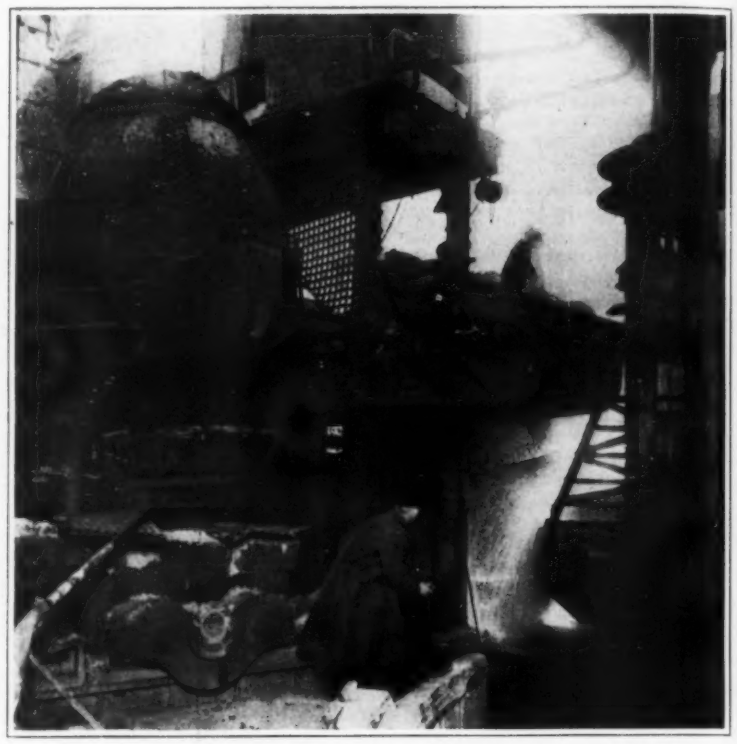
Emptying a ladle of molten metal from the blast furnace into a pig iron mixer



A Bessemer converter that transforms melted pig iron into steel suitable for rails and similar uses

Typical Scenes in a Steel Plant

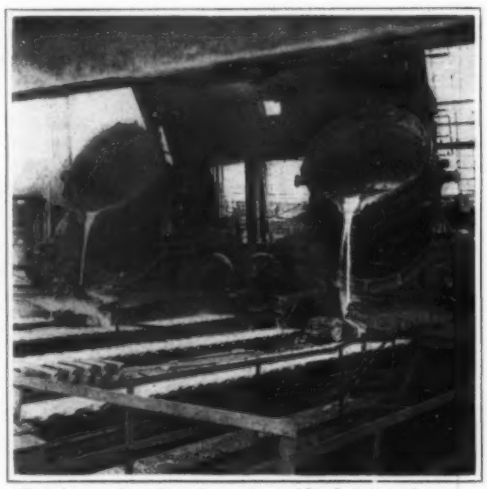
Some of the Processes in the Manufacture of Iron and Steel

In former years statisticians watched the grain crops, especially of wheat and corn, which they considered the gauge of our material prosperity, but of late it has become apparent that the consumption of steel is a much surer indication; for America has become essentially a manufacturing country, and even the farms are now cultivated by machinery, and in every kind of enterprise steel is the most important essential. The amount of steel required by our people is, therefore, a sure indication of prosperity, for in times of plenty people are buying immense quantities of steel to build new railroads, new factories and the machinery for them; buildings of every kind require great quantities of this material and the farmer is seeking new and more machinery. Steel therefore is the universal essential; and today there is an additional demand to make good the ravages and waste of the war.

The manufacture of steel is such a great subject that its story cannot be told in a few words, but the accompanying illustrations give a few glimpses at some of the spectacular operations to be seen in a steel manufacturing plant.

After the iron ore has been melted in the blast furnace it is passed directly to other furnaces, or converters, that change it into steel. But what is steel? Unfortunately no exact definition of steel has ever been evolved, for the name has been applied to a vast variety of materials, but in a general way it may be said that steel is a much purer metal than the initial cast iron, as it comes from the blast furnace, and the principal difference between iron and steel lies in the amount of carbon contained. Therefore, to convert cast iron into steel the various processes have for their purpose the removal of impurities and also a portion of the carbon of the cast iron. The gradations however are infinite, and in many modern varieties of so-called steel not only are the above operations performed, but certain percentages of other metals, or combinations of metals, are added, making the resulting metal really an alloy. Such additions may be Manganese, Chromium, Nickel, Tungsten, Molybdenum, Uranium, and some other of the rarer metals, which give the steels that contain them special qualities of toughness, hardness and the ability to resist shocks.

These are matters of considerable intricacy, and the present remarks will be confined to the primary process illustrated. To make iron and steel economically the processes must be continuous, for it would be impossible to allow the fires in the great furnaces to die out, after the furnace is once brought up to the proper temperature, as long as the lining of the furnace will last. Consequently there are always a number of furnaces for the different processes always in operation. To make good steel it is necessary to have iron of a known composition, and to maintain this very closely at all times; but small variations must necessarily occur in the operation of the immense blast furnaces, and to control this, and also to regulate the supplies for the following furnaces, the metal from two or more blast furnaces is run into a large common reservoir, or mixer, and the mixture of the different melts compensates for any slight differences in composition.



Pouring molten iron into pig molds that travel on an endless chain under the filling spout

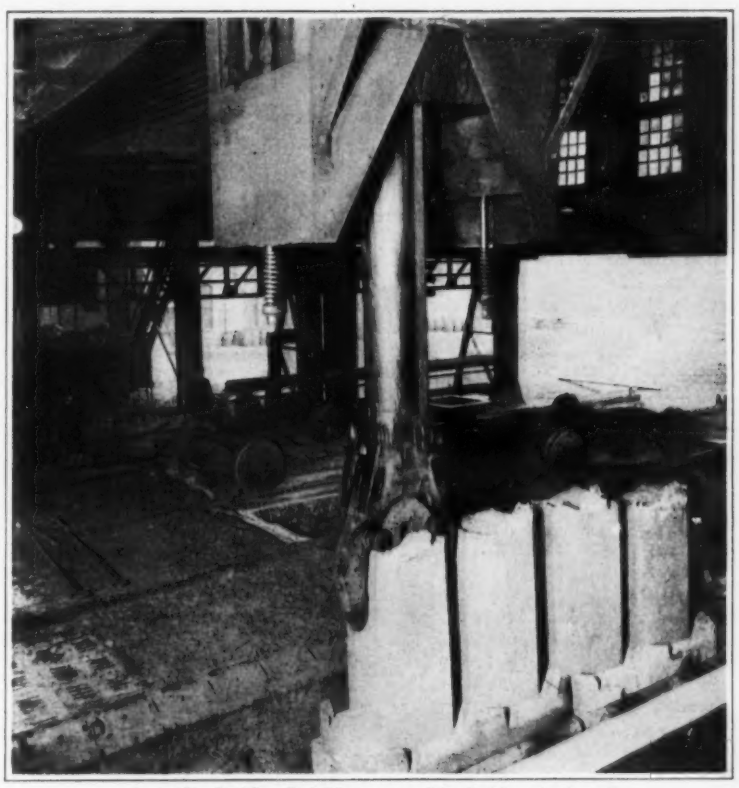
From the mixer the molten iron is poured into the converter; and there are several kinds of converters in which the steel making process is slightly different. Formerly practically all low carbon steel, which is the kind used for railroad rails, machinery, bridges, buildings, for making sheets, bars and wire, was made by the Besemer process, and a Bessemer converter is shown in operation in one of the pictures. This is an egg-shaped vessel into which the crude melted iron is run, and then a powerful blast of air is blown through the metal. This oxidizes the impurities, and also the carbon, and the flame from these burning materials pours out of the mouth of the converter in a dazzling column, which can be seen at the upper left side of the photograph. After as much of the impurities as possible have been removed, the air blast is shut off, the amount of fresh carbon that is required in the steel is then added to the metal, which is then poured into ingots, ready for further operations. It would at first seem that blowing air through the melted metal would at once chill it, and this would happen if it were not for the oxidizable matter contained in the iron, such as silicon, manganese, etc., but as the air is forced in in fine jets it combines with these matters and oxydizes them with considerable violence, and the result of this chemical action is to generate so much heat that the metal is hotter after the blowing than before.

While the quality of material produced by the Bessemer process is particularly suitable for some special purposes, before mentioned, it is not as well adapted for castings, and for this and a number of other purposes better steel can be made by the "open-hearth" process, in which the melted cast iron is run into a large furnace that has a large, shallow trough or bowl, lined with refractory materials. This furnace is heated by a gas flame that plays over the surface of the metal and gradually oxydizes the impurities. In this furnace very much larger quantities of metal can be worked at one time than in the Bessemer converter, but it takes much more time. The great advantage of the open-hearth process is, however, that the operation can be more accurately controlled, and consequently not only is the quality produced more certain, but steels of different characters can readily be turned out.

If rails, bars or sheets are required the molten metal is run into a big ladle, which is quickly transferred by a power crane to a location over the ingot molds, and the metal is run into the molds as they pass under a spout in the bottom of the ladle. The steel quickly sets in these molds, which are made of iron, and after traveling a short distance the mold is lifted from the partially solidified ingot by a special crane. Then the white hot ingot is picked up by a great steel mechanical hand, which places it on a small railway truck that carries it directly to the rolling mills, where it is first placed in a hot furnace until the interior has solidified, and the temperature has become uniform throughout, when it goes to the mill in which, by a series of passages between heavy rolls, the ingot is gradually reduced in size and form to the desired shape. Often these ingots will weigh three or more tons each, and a three-ton ingot will make two rails, after the imperfect portions at the ends of the blooms have been cut off.

If the metal from the blast furnace is to go into storage, either for future use or for sale to foundries at a distance, it is cast into pigs, and this was formerly done in sand molds formed in the floor of a large building adjoining the furnace. This required a large space, and the heat from the pig beds was most ex-

Pouring molten steel into moving ingot molds



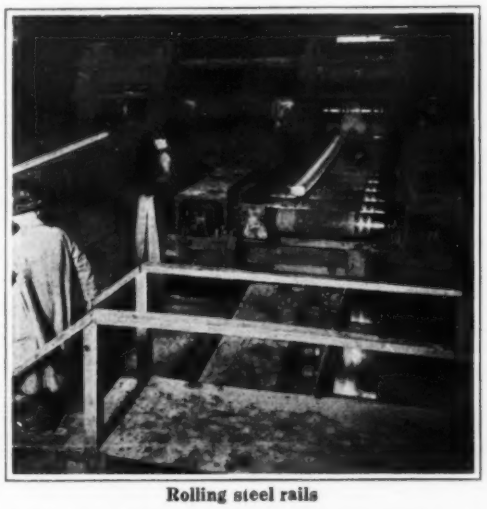
A mechanical hand picking up a white-hot ingot of steel

hausting to the men employed, especially in summer. After casting the pigs had to be separated by blows from a sledge, and then they were usually carried out by the men by hand. After this the sand floor had to be worked over, and a fresh set of pig molds made, all of which took a great deal of time and labor. At some furnaces this method of operation is still followed, but in most places a pig molding machine is used. In this a large number of iron molds are connected together by links to form a great endless chain that travels over a large wheel at each end of the machine, and the upper run is supported by a bed of rollers. This chain is moved along steadily by power, and passes under a ladle of melted iron, which pours continuously into the moving molds. As in the ingot molds, the iron quickly sets in the mold, and as the chain passes over the wheel on the far end of the machine the pigs are dumped out into a railway car ready for shipment. As the chain returns to the filling point it is sprayed with a lime mixture that, as it dries, leaves a coating of whitewash on the mold that prevents the melted iron from sticking to it. One of the illustrations shows two of these pig casting machines, each of which is equipped with two lines of molds. It will also be noticed that each of the big ladles is mounted on a heavy railway car of special construction, by means of which the ladle may be transported a mile or more from the melting furnace to the casting machine with its glowing load of liquid hot iron.

Dellwik Process for Completely Gassifying Coal

In view of the atmosphere of controversy which at present surrounds the problem of carbonization, and particularly the future methods to be employed, it is interesting to refer to endeavors which are being made in the direction of the complete gasification of coal and coke in one operation. It is generally known that if a ton of coal is treated in a special plant for the purpose it may, apart from the ash it contains, be converted entirely into gas, of which product it will yield some 65,000 cu. ft. having a calorific power of about 375 B.Th.U. The "Double-Gas" plant for this purpose is the invention of an Englishman, and particulars are now to hand of a plant which is being employed for the same purpose in Germany, and which is made by the well-known Dellwik Water-Gas Company of Frankfort.

The plant posesses some novel features, but consists in the main of a producer, the lower portion of which is divided into two halves by a curtain wall. Coal is fed into the upper portion and is converted into coke before reaching the divided chamber. The process is very similar to that employed with the ordinary type of water-gas plant, in that air and steam are admitted at intermittent periods; but in this case a superheated supply of air is utilized, and by this means the fuel in the coke chambers is raised to a temperature of 1,400 deg. C., the producer gas being taken off at a point which corresponds with the zone where the coal is completely changed into coke. During the gas-making period a gas outlet is opened above the coal bed, superheated steam is admitted to the base of the producer, and the water-gas thus produced rises through the entire column of coal. This water-gas at the time of its formation is at a temperature of some 1,300 deg. C. and provides the greater part of the heat for the carbonization of the coal, the gases from which are swept from the producer and carried through subsequent plant of the ordinary type for the removal of sulphuretted hydrogen, tar, and ammonia. Condensation is largely effected in the upper layers of the coal bed so that the gas leaves the producer outlet at a temperature of only some 200 deg. C. The producer gases



Rolling steel rails

yielded during the blowing period are not wasted, but are utilized for superheating the steam for gas-making.

The duration of the intermittent periods of blowing and gas-making varies in accordance with the class of coal employed, but generally speaking the "blow" continues for from one to three minutes, while gas-making may be carried on for from five to ten minutes, and it is found that by employing an excess of steam a maximum of ammonia is obtained. An unsatisfactory feature of the process, a feature which is absent from the English system, is the necessity for admitting a certain quantity of air during gas-making. It is said that the quantity of heat demanded for the coking of the coal is greater than that which can be supplied from the stream of water-gas, and hence the necessity for introducing air; but it seems that by modifications in the working it is possible to produce a gas of moderately high calorific power or one of lower quality. From the analysis given by the Dellwik Company it appears that when a comparatively good coal is employed the final mixture of gases obtained contains 50 per cent. of hydrogen, 10 per cent. of methane, 30 per cent. of carbon monoxide, and 1 per cent. of unsaturated hydrocarbons. The calculated calorific power of such a gas is 384 B.Th.U. per cu. ft., and in this respect it corresponds very closely with the suggestions recently put forward for the provision of a low-grade gas.—*London Times Engineering Supplement.*

Utilization of Rice and Its By-Products

A number of samples of Burmese rice have been examined, classified, and analyzed, all of which would be suitable for starch manufacture and brewing. In these industries the broken grains are employed, and it is not considered advisable to grow special varieties for the purpose. For starch manufacture a rice of medium hardness with low protein content is preferred. The variation in the percentage of starch is not large, and this percentage is not necessarily an index of the manufacturing yield; variations in the fat content have no influence. "Red skin" is objectionable, as it gives a dark solution when the grain is softened by alkali. Yellowness of the grain, generally caused by heating in transit, is also objectionable. Fully matured rice is preferred as being freer from undersized granules. For brewing, rices with a minimum fat-content and maximum percentage of starch give the best results. *Rice straw for paper-making.* A sample of Egyptian rice straw has been tested, containing moisture, 11.8; ash, 17.7; cellulose, 50 per cent. The length of the ultimate fibers was 0.6—3.0 mm.; mostly 0.9—1.3 mm. On digestion for four hours at 140° C. with 14 per cent of caustic soda the yield of dry pulp was 44 per cent; with 10 per cent of soda, 50 per cent; and with 8 per cent of soda, 52 per cent, all expressed as dry pulp on air dry straw. These pulps all bleached easily to a pale cream color, almost white. On digestion for 12 hours at 140° C. with 20 per cent of lime, the straw yielded 56 per cent of yellow straw pulp suitable for boards and brown papers. The above experiments showed that a good bleaching pulp could be obtained with an unusually small consumption of soda, but this advantage is partly counterbalanced by losses in the recovery of soda from a material containing such a large proportion of silica. *Rice husks.* The sample examined contained on the dry substance 14.7 per cent of ash and 42 per cent of cellulose; the fibers varied in length from 0.5 to 1.5 mm., being mostly 0.5-0.7 mm. When digested for 4½ hours at 140° C. with 16 per cent of caustic soda, the husks yielded 36 per cent of dry pulp on the air dry weight. The pulp contained a large proportion of gelatinous material and could not be bleached satisfactorily. It gave a very weak and brittle paper, and could not be used in paper-making except as a filler in admixture with pulps of longer fiber.—*Note in J. Soc. Chem. Ind. in a paper in Bull. Imp. Inst.*

The Rise of Navigation

(Continued from page 371)

errors in his assumed latitude would affect the computed longitude he assumed a second latitude 10' farther north and got a position twenty-seven miles ENE of the former position and toward the danger. A third assumed latitude still farther north gave a third point twenty-seven miles still farther ENE of the first point. Upon plotting these positions on a chart they were seen to be on a straight line and this line passed through Small's light off the coast of Wales. Credit is due Sumner because he realized then that anywhere on the line he had determined the altitude of the sun at the time of observation would have had the value he measured, and that such would be the case only on that line. He therefore assumed that he was on that line and, keeping his course ENE along it made Small's light in less than an hour. After hours of uncertainty off a rocky lee shore in the midst of a winter gale what must have been Captain Sumner's relief when the lighthouse appeared ahead. Later it developed that at the time of his uncertainty his latitude by dead reckoning was eight miles too far south and his longitude forty-five miles too far west. The result to the ship might have been disastrous had the wrong position been adopted.

In using Sumner's method in its simplest form, altitudes are measured of two suitable objects in quick succession or of the same object at two suitable times. Each observation gives a line upon which the ship must be situated. The intersection of these two lines of position gives the position of the ship. If the two observations are separated in time and the ship is moving, dead reckoning must be used to allow for the ship's change in position between observations.

Important advantages of the line of position methods are not hard to find. Every observation for position is treated in the same way. The method makes clear to the navigator how much information his observation actually yields. With available tables, including Lord Kelvin's Sumner Line Table, the calculations may be completed entirely without logarithms and with a minimum amount of work. When the value of the newer methods is realized by navigators it is not to be doubted that calculations for position will be based unversally on the Sumner line.

In considering the foregoing methods of fixing astronomically the position of a ship it is evident that, always when the two elements of latitude and longitude are determined by Sumner's method, the navigator has to depend partly on dead reckoning; also during cloudy weather out of sight of land he has to depend entirely on this method for his knowledge of the ship's position. Clearly then frequent determination of the error of the compass is a most important duty. In practice this error is found very simply by comparing the compass bearing or direction of a heavenly body with its bearing, determined by calculation if necessary, but usually taken from a table.

The total error of the compass includes that due to actual known variation of the needle and also that due to deviations caused by the attraction of the iron of the ship. The former error can be found from charts and easily allowed for, but the latter is variable and uncertain and thus makes necessary the frequent determination of compass correction. It is customary to reduce the deviation error as much as practicable by the use of artificial magnets, as well as spheres and bars of soft iron, mounted about the compass before the ship leaves port, but no arrangement known effects a permanent correction.

A careful record of everything pertaining to the navigation of the ship with the results of all observations and calculated positions is kept in an official book, called the Ship's Log. Each day at noon the ship's position is computed by dead reckoning from the previous noon and also by astronomical observations, when such are available. The course and distance made good from the previous noon are then computed using astronomical position if available. Finally the course and distance are computed from the position of the ship at noon to either the port of destination or some prominent position or danger near which the vessel must pass.

The needs of our rapidly expanding naval forces and the demand of our new merchant fleet for thousands of officers have centered attention in instruction for the preparation of navigators. The Shipping Board schools, the naval schools and colleges, and also our universities are making a creditable effort to meet the situation. The concrete result in trained men will undoubtedly fill all important requirements. But in addition it is reasonable to think that progress in the improvement of the art of Navigation, in this country at least, will be stimulated. Awkward relics of former times may be hurried aside. Such obstacles as the astronomical day may be removed. Certainly beneficial co-operation will follow in greater measure among navigators on vessels of the Navy and the Merchant Marine and those who are experts in related fields on shore.

The Rhone River Project

THE project for making an extensive use of the Rhone river in order to develop the national resources is one that is coming into prominence in industrial and political circles in France at the present time. The various conditions relating to the use of the Rhone are set forth in an able manner by Deputy Augagneur in the Paris daily press. It is the opinion of competent persons that in order to properly meet with the situation, the project should provide for combined operations as follows: 1. Navigation. 2. Hydraulic plants. 3. Irrigation. Plans should be drawn up for all this work in combination and as a vast enterprise on a general scale, in order to obtain the interest of the entire population of the Rhone region and their representatives. Partial measures were in fact unable to succeed, as shown by unavailing efforts in the past, for the different regions were working in opposition and upon different classes of industry. In fact the upper or northern part of the Rhone is to be used for hydraulic power, and the southern part for irrigation, while Lyons and the middle region are more largely interested in navigation. But it is now recognized that a general plan is much to be desired, and that separate or independent work of local importance is not recommended if the final success of the enterprise is to be assured. In considering the industrial utility of the project, it should be noticed that the Rhone can become a source of great activity under proper conditions. From the Mediterranean it leads directly to Switzerland, through a large part of France, and by its tributaries the Saone and the Doubs it affords a waterway to the frontiers of Alsace and to the Rhine. On the other hand it is the navigable route that should be used for transportation of merchandise from the Orient and Africa, and this would enter the Mediterranean port of Marseilles and proceed by way of the Rhone towards central Europe. As regards hydraulic power, this can be obtained in the region of the upper Rhone, the river being more rapid in this part of the country, and together with its tributaries it could be called on for millions of horse power. In the south of France the river becomes wider and runs through a generally flat country in which the soil is of a dry nature, but at once becomes fertile with even a small amount of irrigation. In this part of France the climate is excellent and it favors an abundant vegetation. Irrigation projects have been on foot in preceding periods, but nothing of any consequence has been done as yet. As concerns navigation, this development has been desired for a long time by the population, but it could not be realized on account of heavy opposition from the railroad interests. In short, it may be considered that everything still remains to be done. At the present time there appears to be a decided move in favor of the enterprise on the part of the population of the Rhone basin and their representatives, both Senators and Deputies, and the latter seem inclined to put through the necessary measures. It should be remembered that this basin covers upwards of 50,000 sq. mi., representing about one-fifth the area of France, while the population is about 10,000,000, or one-fourth the total. Considering the fact that so large a part of the population of the country is directly interested in the enterprise from an industrial and economic standpoint, it will be seen that we have here not a local but a national issue. Of course the increased prosperity of the region will be felt all over the country, not only as concerns movement of traffic, exchanges and commerce in general, but also in the field of electric power from the hydraulic plants, for this can be transmitted to other regions. It is recommended that the government should take direct charge of the enterprise, and secondarily it would make use of all co-operation available as concerns towns and departments, Chambers of Commerce and private corporations, but the government should be charged with laying out the general plans.

"Soil Sickness" Researches

AN investigation of the soil conditions favoring the appearance of "haverziekte" (oat disease) and "Hooghalensche ziekte" (Hooghalen disease) which have appeared recently in the Netherlands and Germany. The first is attributed to an excess of bases in the soil, and the second to excessive soil acidity. The direct and immediate cause of the appearance of these "soil sicknesses" has not yet been determined, but a close relationship has been established between their appearance and the free humic acid content of the soil, thus enabling the soil to be rendered healthy by means of suitable treatment. Two methods for the determination of the content of free and combined humic acid and the lime requirement of a soil are described, namely, (*a*) by means of cultures of *A. otobacter*, and (*b*) by the aid of a diffusion method on agar plates stained by indicators. In method (*a*) 50 c.c. of distilled water, 2 per cent of mannitol, 0.2 per cent of dipotassium phosphate, and 5 grms. of soil are placed in each of two conical flasks, the mixture is inoculated with *A. otobacter* and incubated at 26° C. A control flask receives in addition some calcium carbonate. The soil is said to be basic or acid according as the bacteria do or do not grow in the flask without calcium carbonate, and it was found that soils causing the oat disease did not favor the growth of the bacteria, while soils affected with Hooghalen disease did favor their growth. To determine the lime requirement of the soil two species of *A. otobacter* were used, *A. vinelandii* and *A. chroococcum*, the former being able to grow at a slightly higher degree of acidity than the latter. The lime requirement of a soil was taken as that amount which just suffices for the growth of *A. vinelandii*, but is insufficient for *A. chroococcum*. The results by this method agree quite well with those obtained by the diffusion method. This latter method is based on the fact that acids and bases, even when difficultly soluble, diffuse in a hydrogel. In a layer of agar colored by litmus, small cavities are made without piercing the layer, and it is found that acids or alkalis placed in these cavities develop a surrounding zone of acid or alkaline reaction in the agar, and this effect is perceptible down to a dilution of *N*-5000. In the determination of the free humic acid content of a soil, 10-grm. portions of soil are heated for three hours at 100° C. with increasing quantities (5 mgrms. at a time) of calcium carbonate, and their reaction is then tested on the agar plate, the results for the soil being expressed in mgrms. of calcium carbonate on the soil or on its loss on ignition. For the determination of total humic acid content (free and combined), the soil is boiled with *N*-10 hydrochloric acid, filtered, and washed free of chlorine, and then the total humic acid is titrated by the agar plate method. For the determination of excess of alkali in a soil, increasing amounts of hydrochloric acid instead of calcium carbonate are added to 10-grm. portions of the soil and the process continued as above. From the results of a large number of analyses the authors find that for any soil, whether sand or peat, acid, neutral or alkaline, the total humic acid per grm. of loss on ignition is always constant and equivalent to about 80 mgrms. of calcium carbonate. They have determined the ratio of free humic acid: combined humic acid, and state that if this ratio is greater than 0.6 the soil is "hyper-acid"; if it is between 0 and 0.5 the soil is healthy, the best percentage of free humic acid being 25 per cent of the total. The content of free humic acid is increased by the application of such salts as potassium chloride, magnesium chloride, and ammonium sulphate, and decreased by the addition of lime, magnesium or sodium carbonates, and sodium nitrate.—*Note in J. Soc. Chem. Ind. on a paper by N. L. Solmgen, A. Kuetemann and K. T. Wieringa in Verstag, Van Landbouwk Onder oek der Rykslandbouwkproefstat.*

Batik Dyeing Process

A SPECIAL display of textiles dyed by the Batik process was exhibited at the Leipsic Spring Fair this year and in a statement issued by the *Textil Zeitung* information was given that the use of the process was spreading rapidly among manufacturers and was likely to become a great and important branch of the textile industry after the war. "Batiking" is well known to United Kingdom manufacturers and United Kingdom firms were the first to offer to the Straits Settlements, where it was originally introduced from Java and is exceedingly popular, goods dyed either by the same or a modified batik process. The *Textil Zeitung* claims that the process has been amplified and perfected in Germany during the war. Certain tissues, which hitherto would not take certain colors, can now be dyed. Stuffs, blouses, stockings, hats, etc., can be redyed by it when they are old and can take a lighter color or be entirely changed. It has been possible to use apparently useless or faded goods. The following account of the batik process written by an authority in the Netherlands East Indies is of interest: To batik signifies to cover a cotton fabric with a thin ground of wax before plunging it into a bath of dye so as to preserve from the latter certain parts of the stuff thus forming a design. This operation, repeated several times in succession but with a dye of different color on each occasion, and with the stuff recoated so as to preserve different portions from the dye, finally produces a design which is often of real artistic value.—*Jour. Ind. Eng. Chem.*

Liquid Crystals*

EVIDENCE has been accumulating during the last few decades that there is justification for speaking of "liquid crystals." The term certainly does not appear to accord with the time-honored distinction of the three states of aggregation, the solid, liquid, gaseous. Nor do bodies like pitch and wax and others which gradually soften without having a definite melting-point exactly fit into this classification. But crystals, substances, which in solidifying assume definite, though varying shapes with straight edges and plane faces, and which are characterised by peculiar optical and other physical properties not found in either amorphous or in liquid substances, seem to be the solids *par excellence*, and it is difficult to imagine such substances to partake simultaneously of the characteristic properties of solids and of liquids. Yet we know now a large number of crystal-like bodies of more or less constant shapes, which unite when they meet, forming twins which may split again, which may be distorted into spirals, and which not only possess some of the specific properties of crystals to an enhanced degree, but actually display certain optical properties for which scientists have so far been looking in vain in solid crystals. These liquid crystals may drift in a trough across which wires have been stretched and float right through the wires to close up again and to reassume their original shape and properties, very much like the proverbial ghost floats through the walls and is left unharmed by bullets and sword thrusts. These liquid crystals are real, though they are best studied under the microscope and polariscope.

The term "liquid" crystals was introduced in 1888 by Professor Otto Lehmann of Karlsruhe, who remains their chief investigator. He was soon joined by an ardent but critical small group of workers, and the optical side of the phenomena and their theoretical bearing in particular have been much discussed. Demonstrations of the beautiful color effects of liquid crystals observed in polarised light have been repeatedly given over here, and it is they which first attracted wide attention. In most of these experiments some of the original solid substance is placed on the microscope stage between two glass plates (one of which may be a lens) to form a layer about 1 mm. in thickness which is heated from below. Examining cholesterin benzoate in this way in 1888, Reinitzer observed that the liquid existed in two phases the one melting from the solid at 145 deg. C., the other forming at 179 deg. The former turbid phase proved doubly refractive; at one spot a deep violet color shot up which spread all over the liquid to vanish again; on further heating the violet reappeared, the liquid cleared, and solidified on the cooler portions of the glass to colorless crystals. The two phases were reversible. When the heating of the stage is central, the hottest liquid above the flame is generally isotropic, the cooler layer surrounding this central liquid is anisotropic (doubly refracting), and the solid crystals settling further outside have their own properties; we will presently explain the terms briefly. A normally anisotropic liquid was not known at the time; for this and other reasons Lehmann, who was engaged in similar researches, proposed the name "liquid crystals"; others preferred to speak merely of anisotropic liquids. More liquid crystals were found; Gattermann prepared to *p*-azoxyanisol and the *p*-azoxyphenetol, which have become famous in these researches, and D. Vorländer succeeded in preparing 170 new organic compounds of widely different types and constitutions which had the desired peculiarities. More have been added to the list since.

All homogeneous liquids are isotropic like amorphous bodies, glass and crystals of the regular system, that is to say, they propagate light, electricity, and stresses equally in all directions without showing any preference for any direction—unless they be strained mechanically or thermally (the case of rapid cooling of glass), or by magnetic or electric fields. They then turn anisotropic; that is, there are preferential directions for the propagation of light, &c., and these directions are connected with the one or more optical axes of crystallisation or with the lines of stress. In the quadratic and hexagonal systems the one optical axis is the crystallographic axis which is longer or shorter than the other two or three axes, and any ray not parallel to that axis is split into two rays, which are polarised at right angles to one another. Owing to interference or to circular polarisation beautiful colors appear at the same time when the observations are made between Nicol prisms, and as the absorption of light is likewise different in different directions, the colors may also change with the direction (dichroism).

Many of those features now are observed in perplexing complexity in liquid crystals, and it seems difficult in particular to conceive liquid crystals on the modern view that the atoms of a crystal are arranged in definite positions in a rigid space lattice. Such difficulties were not novel to Lehmann, however. He had found five modifications in the solid crystals of ammonium nitrate, having transition temperatures lying between — 16 deg. and + 125 deg. C.; he had bent these crystals to rings without changing their transparency or solubility; silver iodide, he had observed, exists between 146 deg. and 450 deg. C. in a viscous mass, yet in regular crystals; it was known that rock salt crystals are easily bent by small loads and remain permanently deformed (W. Voigt). Moreover, small crystalline particles are believed to slip over one another under stress. The rigid space lattice did not then appear to be essential to crystallisation. Many of Lehmann's liquid crystals do not look like crystals. They may be slimy spherical drops, threads, conical, doubly conical (like two tops placed with their bases in contact); or they may appear decidedly polyhedric in shape like real crystals, or ribbon-like splitting into their constituent parallel rods, &c. Even the simple spherical drops, however, show an axial spindle which by preference places itself at right angles to the glass. Two diamond-shaped crystals may unite to a Y, the two wings of which flap together the next moment, perhaps to separate again. The already-mentioned experiments of cutting up the crystals by letting them drift against wires was made with ammoniumoleate hydrate. Air bubbles, dye particles suspended in the fluid, and portions of the solvent take up regular symmetrical positions in the crystals, or between them, as if they formed part of the crystal structure.

Let us briefly examine the different properties and the suggestions made for their explanation. The first objection raised against liquid crystals was that the crystal floating in its solvent or in its own melt was not pure, but contaminated with solvent or impurities. That objection was met by preparing the pure substance and contaminating it purposely; the phenomena remained substantially the same. The individual character of the crystals is little disturbed by heat, except that the drops begin to rotate, especially when lying flat on the glass stage—why, is not clear, but there is a strong general tendency to rotation. When a drop is flattened out, it changes its structure; a divided drop gives two halves of the original shape. In the magnetic field the crystals or axes place themselves parallel to the lines of force, mostly in the same direction, sometimes in the opposite direction (C. Mauguin). When the impurity hypothesis broke down, an arrangement in homogeneous layers was proposed. The rotation phenomena and other facts, also that particles of the solid phase adhering to the glass seemed to serve as nuclei for the subsequent crystallisation and other influences of the glass plates seemed to support that view; but the behavior of the liquid crystals between mica (instead of glass) plates was altogether peculiar. Further, if the liquids were suspensions or emulsions of the one phase in the other, or in the solvent, the clearing of the turbidity should be gradual, while it is sudden, and capillary experiments on the internal friction and experiments on the dielectric constants of the two phases fail to support that assumption. The swarm-hypothesis, a special case of the emulsion hypothesis, did not prove satisfactory either (E. Bose, W. Nernst). Finally, S. van der Lingen, submitting liquid crystals to X-ray examination, did not discover any evidence of a space-lattice structure.

Some of the optical phenomena are exceedingly curious. The azoxyphenetol shows between crossed Nicols the dark cross of optically active crystals (circular polarisation) and alternately white and yellow tones in the quadrants. This appearance is not changed when either the polariser or the analyser is removed, except that the quadrants change places. There is hence rotation of the plane of polarisation. While, however, a quartz plate of 1 mm. thickness would call forth a rotation of about 25 deg., these rotations were much greater; anisal cinnamonic acid gave rotations of 4,000 deg., a cyanogen compound of this body even 12,000 deg. Investigating these peculiarities together with F. Stumpf, Woldemar Voigt, of Göttingen—an authority on crystallography and optics—partly with the aid of a novel Newton-ring apparatus which can be turned about its vertical axis while under oblique illumination, obtained evidence of quite extraordinary intense absorption and dichroism, and he observed phenomena—as we stated in the introduction—long looked for, but not so far been realised with solid crystals. These Voigt explains by suggesting a zone of missing double refraction, in other words, a cone of optical axes in these crystals, the possibility of whose existence had long been recognised. Thus some difficulties seem to have been solved, others await solution. We should add that Svedberg, of Upsala, who investigated the electric conductivity of liquid crystals, has recently taken up the theoretical studies together with C. Bergholm, Y. Björnstahl, and others. An atlas of the brilliant color phenomena was published some years ago by Hanswaldt.

If we sum up we may say that a *prima facie* case for the existence of liquid crystals seems to have been made out. The analogies between anisotropic liquids and real crystals certainly go far. The molecules of certain classes of liquids are capable of assuming definite shapes, which they retain and reassume when disturbed, and of arranging themselves in directions parallel to their axes; there is little evidence of orientation normally to that axis. Whether they could be fitted into a space lattice is uncertain. Optically they behave like uniaxial crystals, and it is noteworthy that certain peculiar phenomena as to double refraction and color which theory had predicted for crystals have never been observed yet, except in those liquid crystals, and that other phenomena appear much more striking in them than in solid crystals. The liquid crystals are affected by magnetic and electric fields, and show a preferential electric conductivity like crystals. The action of heat is far less disturbing than in the case of gases. But the phenomena seem to be limited to certain temperature ranges. Outside these limits there must hence be molecular or atomic rearrangements or constitutional changes, the nature of which is unknown; thermodynamically the phenomena seem to be explicable. To account for the analogies W. Voigt suggests that the bricks of solid crystals are the atoms, and that the bricks of liquid crystals are the molecules. Regular molecular aggregates may have different properties from atomic aggregates. The atomic, as distinct from the molecular, structure of crystals would be in accordance with the results of the investigation of the solid crystal structure by X-rays. The atoms of crystals are held together by the same strong polar forces of enormous intensity at small distances which bind the atoms to chemical compounds. The cohesive forces, which keep the molecules of real crystals together and decide their definite shapes, are weak in anisotropic liquids; hence the individual masses may appear in spherical, conical or polyhedric shapes, according to their consistency. In that continuity of form Voigt still sees evidence of a difference in principle between solid and liquid crystals. Lehmann does not accept that distinction of atomic and molecular bricks. He ascribes to the solid crystals a definite limit of elasticity which the liquid crystals do not possess. Going beyond the atom and molecule M. Born has attempted to extend the theory of fixed dipoles to anisotropic liquids, and electrons have, of course, been called into requisition. There remains the fundamental objection, originally raised against the suggestion of liquid crystals, that the complex organic compound in question may be partially decomposed and hence heterogeneous. But the provisional acceptance of "liquid crystals" will not impede the further investigation of these problems.

We feel tempted to conclude with two plain questions: Can we conceive the ultimate particles of fluids to be anything but solid? And must not regular arrangement of the atoms or molecules precede solidification in crystallisation?

*From *Engineering*.

Cadmium as Tin Substitute in Solder

CADMIUM appears as a promising substitute for part of the tin in solders. The bureau has been developing such a solder, and laboratory test together with manufacturing experience so far point to a composition of 80 lead, 10 tin and 10 cadmium as being practical for many of the purposes for which solder is required. This solder has been tried in the manufacture of tin cans, on roofing materials, and for electrical joints with encouraging results in all cases. Before using it for food containers, however, it will be necessary to ascertain its toxic properties under various conditions. A test has also been made of it in the manufacture of automobile radiators with most satisfactory results.

The tensile strength of the cadmium solder is about the same as that of 40-60 solder, but the ductility is approximately twice that of the ordinary solders. The point of complete liquation is only slightly higher than that of the ordinary composition of solders, while the range of solidification is considerably greater.

Because of the preponderance of lead in the cadmium solder, the price of it is very reasonable; with the present market prices of the metals involved it is thought that the 80-10-10 solder can be sold at a profit at 35 cents a pound.—*U. S. Bureau of Standards.*

Sound Steel by Lateral Compression*

Experiments With a View to Eliminate Waste

By Benjamin Talbot

In the presentation of this paper the author is continuing his work and investigation in the hope of producing a larger percentage of commercially sound steel from the upper portion of the ingot. The following description of the investigation may be of interest to metallurgists and others upon this very important subject:

It was decided to use a refractory-lined top for the molds, as the use of these localizes the pipe in the ingot and also confines the segregation to the upper portion more than is the case when the iron molds are used. The refractory lined top also keeps the surface of this portion of the ingot hotter than the lower portion which is in contact with the iron sides of the mold. It was also decided to continue the investigation by laterally compressing the top portion only, as it was thought to be unnecessary to endeavor to improve the lower 80 per cent. of the ingot, this being sufficiently sound and regular in composition for all ordinary purposes when refractory tops are made use of, and therefore the compression of the whole ingot would only make the proposed machine much larger and stronger than would otherwise be the case, and would also increase the time and cost of the compressing operation.

THE APPARATUS USED.

The aparatus decided upon was a hydraulic press, so designed as to make a depression upon two or upon all the four sides of the ingot, and the depressions so made were to be of larger area than the cavity which would form in the ingot were it allowed to go cold. This depression is made either oval or fluted in shape. Such a press is a compromise upon the Whitworth and Harmet methods. The idea of both these processes embraces the compression of the entire ingot in the mold itself, and consequently these molds have to be of a very strong structure to withstand the immense pressure exerted, and the time taken for the compression makes the process slow and very expensive. In the new method of pressing, the ingot is separated from the mold, and the upper portion is pressed at a time when the outer envelope is thick and strong enough to retain the pressure, but while the center is still sufficiently liquid.

The hydraulic press finally decided upon was designed and built upon the lines shown in Fig. 1. It will be observed that the press has four rams so placed that each face of the ingot can be operated upon as desired. It is furnished with a lifting table to take care of any difference in length of the ingot. To work the method successfully, care must be taken to have sufficient temperature on the surface of the top portion of the ingot which has to be squeezed, and therefore it is desirable to have a difference in temperature between the top portion of the ingot and the lower portion. In practical work we have found it best always to use an ingot of standard size, and hitherto ingots of 3½ tons or 5 tons have always been used. All the ingot molds used in the investigation were furnished with refractory-lined tops.

The average temperature over a number of 3½-ton ingots when stripped between an hour and an hour and a half after casting was found to be 1140 deg. C. at the top in contact with the bricked portion of the mold, and 940 deg. C. at the bottom where it has been in contact with the iron side of the mold. With a difference of temperature such as is here indicated, and at the temperature given, the ingot is sufficiently hot to be pressed at the top.

From 100 consecutive ingots of pressed steel, nearly all from distinct heats, an average result of 95% of sound steel was obtained, and in no case less than 90% were found. The tests were carried out as follows: A discard of 20 per cent. was cut off the top of the 6-in. billet, without any cropping in the cogging mill, so that the top contains the original top of the ingot, which in ordinary practice is always taken off. This 20 per cent. was then broken up into individual shell lengths, and the fractures of each one examined for pipe, blow-holes, and segregation and surface defects. It will be seen that an average of 95 per cent. of sound steel was obtained from the ingots pressed.

A sulphur print from the planed surfaces of this 20 per cent. discard from one of these pressed ingots, after being rolled down into billets, broken into 6-in. shell lengths of about 133 lb. each and the ends planed, showed very clearly the purer center, the almost total dispersal of the segregate, and the normal outer portion. Although the pressure is applied on the upper 15 per cent. of the ingot only, there is no doubt that its influence is felt somewhat lower, and probably can be traced to a distance of 20 to 25 per cent. from the top.

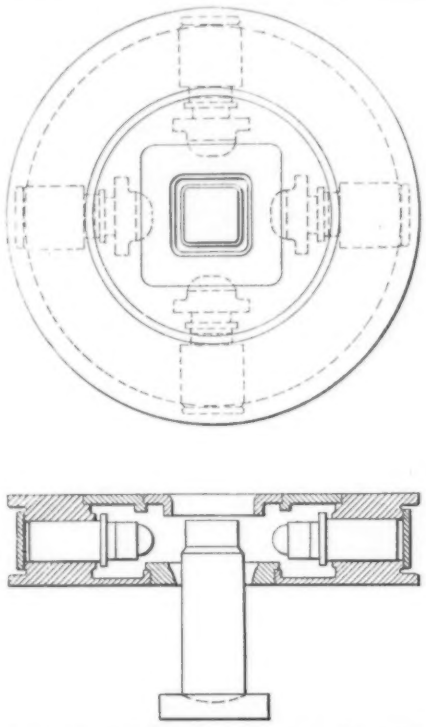


Fig. 1.—Sections of the hydraulic press used to compress to top portion with steel ingots

If the author's paper in the *Journal of the Iron and Steel Institute*, 1913, No. 1, be referred to, it will be seen that the carbon, sulphur and phosphorus in the steel were thrown out into a definite line bounding the purer center. This effect was probably partly due to the use of rolls, as they operated more rapidly than the press. With the press now in use, the segregate is more regularly diffused, and this line is not found. The carbon percentage is somewhat lower in the center for about 10 per cent. of the area of the whole face than the average of the ingot. The phosphorus and sulphur are also lower in this area, but there can be no objection to finding a lower percentage of these impurities. Manganese and silicon are practically not affected, so that there is no discussion upon these metalloids.

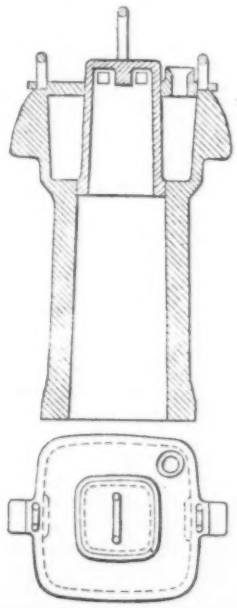


Fig. 2—The suspended century core around which molten slag is poured to form hot tops

We therefore confine the difference found to the reduction in the percentage of carbon, and this raises the question for metallurgists and engineers as to whether there is really any objection in this. If it be an objection, however, it should certainly be preferred to the present condition of having an unknown excess of carbon, sulphur, and phosphorus in a given place, accompanied very often with unsound steel at the same spot. For rails, a somewhat softer center, coupled with sound steel, can hardly be considered objectionable, seeing that a hard wearing surface is desired. For all ordinary material, when the physical tests desired are obtained, it should also not be objected to, especially if economical advantages can be obtained by its use.

From these results one can anticipate what will be obtained from a finished rail, and it will be observed that sound commercial steel can be obtained from the compressed steel to within 3 or 4 per cent. from the top of the ingot, which amount it will be necessary to crop when rolling ingots in a modern mill in which large outputs are obtained, so that by this method the entire ingot, minus its necessary cropping, can be satisfactorily made use of.

COMMERCIAL APPLICATION.

From the foregoing results, it will probably be admitted that a larger percentage of solid steel, fit for commercial purposes, can be obtained if the top portion of the ingot be compressed before its center is entirely solid than is the case with the usual method of casting with refractory tops. The problem, therefore, narrows itself down to one of a practical and commercial nature. If a sufficient increase in the percentages of commercial steel can be obtained rather than producing this amount as scrap to be remelted, and if the difference in price between the commercial product and scrap value is going to be large enough to permit of the installation and operation of the necessary plant, then it will be of interest to see whether the process can be applied in practice upon large outputs.

No one today can forecast future values. We are told to expect a scarcity of raw materials for post-war conditions, and if this should be so, then it behooves everyone more than ever to try to increase yields of finished products and to decrease consumption of raw materials and labor in the production of these products wherever possible.

For the ordinary cheap trades, such as the rail trade, which deals with large outputs, the successful operation of this process means the adoption of a standard ingot of suitable size to suit the working conditions of the plant, and the observance and carrying out of a time table as between pouring, stripping, and pressing the ingot, otherwise the method cannot be satisfactorily made use of. For forging and special trades, which use ingots of sufficient size, there should be no practical difficulties in installing the process if it were found of advantage to do so. In these shops the output of steel is not great when compared to some, and the ingots for many trades are sufficiently large to allow of ample time to compress them.

Where the Bessemer process is used, the difficulties would be small as the heats are cast in a steady progression through the working shift. In a shop with 20-ton converters, casting the steel into 5-ton ingots, one press would easily keep ahead of the converter, as it would squeeze each cast in less time than the converter takes from blow to blow. It follows, therefore, that to deal with a modern Bessemer shop output a press would be required for each converter blowing simultaneously, and that the stripping arrangements must be adequately arranged also.

For stripping and pressing six 50-ton heats of steel of 5-ton ingots the average time taken was 3.2 minutes per ingot. This time will be considerably reduced in a properly designed stripping and dressing plant, as no doubt a period of 2½ minutes from ingot to ingot will be obtainable.

DIFFICULTIES IN OPEN-HEARTH MILLS.

In considering this squeezing process, one can see difficulties in open-hearth shops having a large number of furnaces, some of which cast simultaneously, and where for some reason or other best known to the furnace operators, they seem to prefer to flood the shop

*Abstract of paper read before the Iron and Steel Institute. From a report in the *Iron Age*.

with a large number of casts in a few hours, rather than have the casts more evenly divided over the entire shift. This difficulty should not be encountered so much in those shops in which the Talbot steel process has been installed, as they have fewer but larger units. It will have to be met in large open-hearth shops, however, using fixed furnaces of smaller capacity.

With a 5-ton ingot, we know from the results already obtained that if the ingot be taken and pressed at about 1½ hr. after pouring, and another be taken at 2½ hr. after teeming, we obtain in both cases sound steel, as no pipe is found in the rolled product. It follows, therefore, that there is a period of some 60 min. during which the operation of squeezing a particular ingot of the size given can be satisfactorily carried out. In casting a 50-ton heat of steel into 5-ton ingots, a period of at least 30 min. is necessary from the time the steel begins to run from the furnace into the ladle to the time the ladle is empty.

The press, with a properly arranged stripping plant, will squeeze 10 ingots of 5 tons each—that is, the whole cast—in 25 min., and therefore one press can take care of two casts which may have been poured simultaneously, as there is a period of 60 min. during which any ingot can be successfully squeezed, and the whole 20 can be readily squeezed within this period. For each press, therefore, that might be installed two casts poured simultaneously can be taken care of, but if the output of steel for any one or more hours should be larger than this an increased number of presses would have to be installed to take care of the fluctuating hourly supply of ingots. For this reason the importance of spreading the tapping of furnaces more evenly over the entire working shift is seen, as it saves duplication in the stripping and pressing plant.

As has been previously stated, the localization of the piped portion of the ingot, while retaining a higher temperature in such ton portion, is successfully brought about by furnishing the upper top portion of the ingot with a refractory top, such refractory top being in practice made by ramming ganister or lining the top portion with firebricks. With large numbers of ingots in use, this is found to be an expensive method, requiring a large number of bricklayers to keep them in repair, as the brick tops only go for a few heats before requiring renewal.

A CHEAP REFRACTORY TOP.

The author has devised a cheaper method of making these refractory tops to the molds, and this is illustrated in Fig. 2. The method consists in providing an ingot mold with a suspended central core as shown in the figure, and pouring liquid slag into the space formed between the core and the recessed side of the mold. As soon as the slag has become solid the core is removed, when the mold can be brought into use, and the steel cast against the slag-lined part. With suitable blast-furnace slag from 15 to 20 casts can be obtained before renewal is necessary, but with more refractory slags, such as the slag from the acid open-hearth steel process, a longer life may be expected before renewal becomes necessary.

A heating, stripping and pressing plant has been designed to take care of from 7,000 to 8,000 tons of 5-ton ingots per full working week. Two presses are provided to cope with a fluctuating supply of ingots, and ample stripping power is installed to take care of the casts as they are delivered under the gantry.

Chemical Analysis by a Magnetic Process

A VERY ingenious method for rapidly and accurately analyzing solutions containing iron and other magnetic elements such as chromium, nickel, cobalt, manganese, and a vast number of their compounds has been devised recently by an Italian chemist, Mr. A. Quartaroli. The details of his technique were published by him in the *Gazetta Chimica Italiana* for March 31, an abstract of which appears in *Le Génie Civil* (Paris) from which we quote. The method which is said to be superior in precision as well as rapidity to the best gravimetric methods hitherto employed in chemical analysis, is based on the following phenomenon:

If we place in a sufficiently powerful magnetic field two magnetic solutions one of which is superposed on the other (Fig. 1) and of different magnetic susceptibilities *m* and *d*, then we observe that the surface which separates the two liquids will be curved towards the one which is the more magnetic (Fig. 2) (in this case the lower), and at the end of a sufficient lapse of time the upper liquid will penetrate the lower (Fig. 3) and eventually assume the form of a distinct drop (Fig. 4), if the magnetic field be sufficiently intense and the difference of magnetism sufficiently marked. If the superior liquid be the more magnetic the phenomenon will be reversed.

Between the two poles *ab* and *a'b'* of an electromagnet (Fig. 1), in the form of circles 25 millimeters in diameter, and connected with the cores by surfaces in the form of the frustrum of a cone of about 45°, we place a small glass tube of the same sort as those used in analyses by the dry method; this tube, which is about 8 mm. in diameter, must pass exactly between the two poles. It has been previously filled with the solution to be tested up to the level *aa'*. The second solution *d*, of known standard, and tinted by one of the colored indicators used in chemical analysis, is added drop by drop by means of a fine pipette whose point is placed in contact with the inside wall of the test tube; in this manner it is easy to obtain a clearly defined surface of separation between the two liquids, and this persists for a sufficiently long time in spite of their miscibility. The liquid is added till it reaches the middle height of the surfaces *ab*, *a'b'*. The inducing current is then turned on and the phenomena defined above are either observed or not observed, as the case may be. A control test consists in observing their disappearance after the suppression of the inducing current. The appearance or disappearance should be produced within the space of a minute, so that the liquids may not have time to mix.

With a field intensity of 5,000 gauss, which is readily obtainable with ordinary electro-magnets, it is possible, for example, to differentiate two solutions whose iron content differs by less than one thousandth part of their average value. With an intensity of 12,000 gauss, also quite easy to obtain, we can determine the quantity of iron in waters so slightly ferruginous that they do not lend themselves to analysis by ordinary chemical methods.

To determine the amount of iron, for example, we operate upon a clear solution of ferric chloride. The solution to be examined *m* is prepared in such wise that a known volume contains a known weight of the ferriferous product to be analyzed. Care is taken to bring the iron to the maximum, to add sufficient barium chloride to precipitate the iron SO_4, and hydrochloric acid to avoid hydrolysis.

We operate by comparing this solution, previously placed in a series of glass tubes, with solutions of known standard until the phenomenon ceases to be observed. The rapid mixture of the two liquids is avoided by a greater concentration in the lower solution of acid or of salts other than those of iron which is indicated by a higher density.

By the magnetic method, operating with standards arranged in a regular series on a definite scale, like the weights in a box of weights, one can rapidly find the standard at which point the phenomenon ceases to be observed. The result is obtained more quickly when one has previously determined the degree of the content sought.

The nature of the ions combined with the iron has but little influence upon the precision of the method. In the presence of chromium and of manganese their magnetic action can be eliminated by transforming them into chromates and manganates.

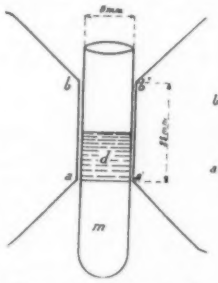
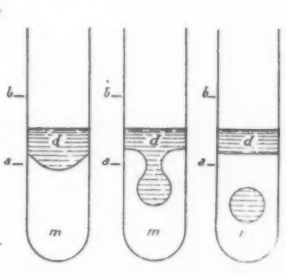


Fig. 1. Diagram of 8 mm. tube showing magnetic analysis



Figs. 2-4 Influence of the magnetic field on the separation of liquids

We can also, and the method is applicable in the case of nickel and of cobalt, determine the magnetic elements by the ordinary chemical methods. We know, by previous measurements, the magnetic susceptibility of their solutions at various degrees of concentration. We measure their effect superposed upon that which the iron produces, and deduct the content of the latter in the solution.

M. Quartaroli has extended the application of the method to the determination of percentages of permanganate and of bichromate of potash, and those of ferrocyanides, ferricyanides, sulphocyanides, and of certain organic substances.

Propagation of Flames Through Tubes of Small Diameter

WHEN an inflammable mixture of methane and air, contained in a tube closed at one end, is ignited near the open end of the tube, the flame is found to travel with uniform speed towards the closed end of the tube The speed of the uniform movement diminishes as the diameter of the tube is reduced as a result of the loss of heat by conduction through the walls of the tube Further reduction prevents the development of the "uniform movement," and when the diameter is sufficiently small, the flame is not able to spread any measurable distance from the point of ignition. Experiments made with gas mixtures containing from 7.6 to 12.0% methane and tubes varying in internal diameter from 3.6 to 9.0 mm. showed that the range of gas mixtures, in which the uniform movement is developed, becomes smaller as the diameter of the tube is decreased until with a tube of 4.5 mm. diameter, only one of the mixtures tested (9.95% methane) was found to propagate the flame. The speed with which the flame is propagated tends towards a constant value of about 35 cm. per second as the limiting mixtures are approached. This speed is considered to represent the smallest speed at which continued propagation of flame is possible in mixtures of methane and air. When mixtures of methane and air, contained in horizontal tubes open at both ends, are ignited near one end of the tube, flame begins to travel with increasing speed towards the other end. When a certain distance has been traversed, the flame vibrates backwards and forwards and in tubes of small diameter such vibration leads to the extinction of the flame. The distance traveled before vibrations begin increases with the length and the diameter of the tube and decreases as the percentage of methane in the mixture approaches that corresponding with the maximum speed of propagation. The relations between these quantities are such that a length of tube of diameter small enough to prevent the passage of flame in a mixture containing say 10% of methane may fail to do so when the mixture contains only 7% of methane, although the former mixture has a greater speed of propagation. In an attempt to realize approximately the conditions under which an inflammation of firedamp takes place within a miner's safety lamp, experiments were also made to determine the length of brass tubes which is required to prevent the passage of flame when a 10% methane-air mixture is exploded. The mixture was contained in tubes 2 cm. in diameter and was ignited at the closed ends of these tubes. By varying the lengths of these explosion tubes it was possible to vary the speed acquired by the flame by the time it reached the brass exit tube. Results obtained with brass tubes of 4 to 8 mm. diameter showed that the increased speed of the flame which is obtained by the use of a long explosion tube, reduces materially the protection against inflammation of the external atmosphere which is afforded by brass tubes. An increase in the diameter of the explosion tubes was found to be without influence on the transmission of inflammation. (See also *J. Chem Soc*, Oct., 1918.)—*Note in J. Soc. Chem. Ind. on a paper by W. Payman and R. V. Wheeler in Chem. Soc. Trans.*

Coal Used by Railroads

IN 1917 the production of coal in the United States is estimated to have amounted to 637,000,000 tons, of which 155,000,000 tons were consumed by locomotives, or 22 per cent of the total. Moreover, to handle this coal, and carry it to the points where it is used requires 3,000,000 cars of 50 tons capacity.

Of the coal required by the railroads about one-fifth is consumed by locomotives when standing idle, and doing no useful work.

It is very evident the problem of economy in locomotive operation is one of extreme national importance, and that if, by carefully concerted action, a small saving can be made in the quantity of coal consumed by each individual locomotive the total would amount to a very considerable tonnage, with the double result of saving coal and transportation.

The matter has been carefully investigated by the University of Illinois, at its Engineering Experiment Station, and the results have been published in Circular No. 8 entitled "The Economical Use of Coal in Railway Locomotives," which contains a great deal of practical information and advice, and should be in the hands of every operating officer of our railways.

Some Cotton Seed Products*

In Their Relation to Present-Day Needs

By Ed. C. De Segundo, Assoc. M. Inst. C. E., M. I. Mech. E., M. I. E. E.

For many decades past, economists have drawn attention to the grave danger of our increasing dependence upon foreign countries for the necessaries of life and for some of the raw materials indispensable to the welfare of our great staple industries. These economic problems have reached an acute stage as a direct consequence of the world-war, and we have good reason now to deplore the fact that we have to draw some 80% of our wheat supplies from overseas, and that only 20% of the cotton required for our spinning industry is obtained from regions within the British Empire.

The fact that Lancashire is dependent upon the United States crop for 80% of its cotton is serious enough, but the menace to the prosperity of our spinning industry is accentuated by the fact that within comparatively few years, the proportion of the American crop spun in American mills has risen from 36% to over 54%.

There can be no question as to the vital necessity of taking steps forthwith to increase the cultivation of cotton within the Empire; and as the production of cotton seed is an inevitable concomitant of the growing of cotton, it is of interest to draw attention to certain products obtainable from cotton seed—and particularly those of the woolly variety—which would serve:

1. To provide a grade of edible oil admittedly superior to that obtained by the method now practised in Great Britain in crushing cotton seed, and admittedly unrivalled for the manufacture of margarine and artificial lard;

2. To provide a flour, containing over five times the protein and fat content of wheat flour, the employment of which would enable us to reduce our wheat imports; and

3. By turning to account the short cotton fibres remaining upon the shell of the woolly cotton seeds, to provide a supply of raw material for the manufacture of explosives, paper, etc.

Probably upwards of 95% of the cotton grown in the world is of the "Upland" or "woolly" variety, frequently referred to as "rain-grown" because it is cultivated under ordinary climatic conditions, *i. e.*, without recourse to irrigation. This seed is covered with an under-growth of "fuzz" or short cotton fibre in addition to the long staple cotton.

Under certain conditions, naturally obtaining or artificially produced, a variety of cotton is grown, which, upon being ginned, leaves the seed "bald" or "black." Practically all the cotton is of long staple and removable in the ginning process. The quantity of such cotton grown is very small compared to the world's crop of some 21,000 bales. The greater portion of such seed comes from Egypt. A very small quantity is grown in the United States.

AMERICAN AND BRITISH SYSTEMS OF CRUSHING COTTON SEED.

(*a*) *British practice.* According to the British practice, the cotton seed—whether it be of the bald or of the woolly variety—is crushed whole just as it is received. The oil is consequently impregnated with the tarry compounds and deep coloring matter contained in the shell, and in spite of recent advances in the processes of refining and deodorisation it is difficult to remove these impurities; indeed some authorities state that they can never wholly be got rid of.

The residue after expression of the oil, consists of the kernel-remains, the shell, the "fuzz," and a certain amount of dirt and foreign matter, forming a cake containing about 4½% to 5% of oil and used only as a food for adult cattle. The presence of the "fuzz" detracts, moreover, not only from the appearance, but from the food value of the cake.

In pre-war times, Egyptian seed fetched from £2 to £3 more per ton than the woolly varieties, and the cake made from Egyptian seed sold at 20s. to 30s. more per ton than that made by the British method from woolly seed.

(*b*) *American practice.* The system adopted practically throughout the United States is that known as the "decorticating system." The cotton seed is run through a "huller" the function of which is to split open the shell of the seed and free the kernel. The mass of broken shell ("hulls") and kernels ("meats") issues from the "huller" and falls upon a shaking sieve, through the meshes of which the meats can pass easily. The hulls matt together by reason of the fuzz upon them, pass over the shaking sieve, and are carried away to a suitable store.

Since the fuzz absorbs oil very readily from the naked kernels in the hulling machine during decortication, it is customary in American practice first to remove a portion of the short cotton fibre in a linting machine. If too much of the fibre be removed, however, pieces of the hull will be more liable to fall through the shaking sieve together with the meats. In first-class practice (in pre-war times) an efficiency of separation of the meats from the hulls of 98% and even of 99% has been claimed with up-to-date decorticating machinery.

The residue of the meats after expression of the oil is called "decorticated cotton seed cake" and is sold as such or is ground to a meal, when it is known as "cotton seed meal." From this meal the cotton seed flour for human consumption is prepared.

During the early years of the development of the industry in the United States, the "hulls" were looked upon as a waste product and were frequently used as a fuel but more often burnt to dispose of them. Subsequently it was found that they could be used as a roughener in the manufacture of feed for cattle—indeed, large quantities of hulls have been fed direct to cattle.

Of recent years, means have been devised for the mechanical separation of the hulls into their component parts of cotton fibre and shell-bran, the former being employed for the manufacture of explosives, paper, artificial silk, cellulose acetate, and other cellulose derivatives, and the latter as a basis for the production of various forms of mixed feeds for cattle.

When the process of decortication is efficiently carried out and a practically complete segregation of the meats (kernels) achieved, the oil expressed is very pure and easily refined, the loss on refining being from 5% to 9%. On the British system, this loss may be taken as from 11% to 15%, and in some varieties of Indian seed, the loss is stated to be from 16% to 20% and even higher.

Twenty years ago the decorticated cake made in the United States contained as much as 10% of oil. In good (pre-war) American practice it was between 6% and 7%. Since the war broke out, American oil millers have succeeded in further reducing the percentage and today some mills turn out cake containing little more than 5%.

In first-class British practice, the percentage of oil in undecorticated cake is from 4.5% to 5%. The percentage of decorticated cake made (calculated upon the weight of the seed as received by the mill) is from 40% to 45%, depending upon the degree to which the seed is linted before decortication. The weight of undecorticated cake, on the British system, is 85% or more.

From these figures it will be seen that as the ratio of the weight of undecorticated cake to decorticated cake is greater than the ratio of the percentage of oil left in the decorticated cake to that left in the undecorticated cake, the percentage of oil expressible, on the weight of seed, by decorticating must be higher than that obtainable by crushing the seed whole (British system)— subject to a small correction for oil left in hulls. The following figures will serve to illustrate this point: The average production of cake and hulls in the United States expressed as a percentage of the weight of the seed crushed, was 43.7% cake and 33% hulls for the years 1910-11, 1911-12, 1912-13 (calculated from the returns of the United States Census Bureau). Taking the percentage of oil left in decorticated cake as 6%, that in the hulls as 0.7% (average for seven years), that in undecorticated cake as 4.75%, and taking the total oil content in average Upland American seed as 18%, the oil expressed from 100 tons of such seed efficiently decorticated would be 15.15 tons. If these hundred tons had been crushed on the British system, it may be calculated that the amount of oil expressed would have been 13.9 tons, or 1.25% less than with efficient decortication.

The presence of shell in the undecorticated cake imparts astringent and other properties to the cake which are not without certain advantages, particularly in the feeding of milch cows at certain times of the year, but this circumstance can, at best, only be urged in extenuation of the British system, not in praise of it. On the improved American system, the defibrated hulls are recovered as a separate product and can, together with other suitable ingredients, be compounded with the kernel-remains of cotton or other seed to produce a balanced ration. The "compounding" of the kernel-remains with the shell and other substances entails of course some additional expense, but apart from the better price such "balanced feed" should command, the cost of grinding and mixing should be more than off-set by the profit on the short cotton fibres recovered from the decorticated hulls of woolly seed, not to speak of the increased value as a roughener.

EDIBLE OIL FOR THE MANUFACTURE OF MARGARINE.

Cotton seed oil obtained by the American method, *i. e.*, expressed from the kernels alone, is unrivalled for the production of the highest qualities of margarine and the oil is easily refined with a smaller loss and at a lower cost than that expressed by crushing the seed whole as on the British system.

COTTON SEED FLOUR AS FOOD.

The credit for the introduction of cotton seed flour as an article of food for human consumption is due entirely to the late Colonel J. W. Allison, one of the pioneers of the cotton seed oil industry in the United States. He first directed attention to the possibilities of decorticated cotton seed meal as a food for human beings in 1876. He stated recently that cotton seed flour is twenty-five times as nutritious as potatoes, five times as nutritious as corn (maize) meal, and four times as nutritious as oatmeal.

Choice cotton seed meal must contain (according to the rules adopted by the Memphis Merchants' Exchange) not less than 49% of combined protein and fat. The average analysis (before the war) is given as 45% crude protein and 6% fat. Owing to the rough and ready manner in which the cake is handled in the mill, impurities and foreign matter are liable to be introduced, and the meal ground therefrom must therefore undergo certain purifying processes in its conversion into cotton seed flour for human food.

The serious attention of the United States Government is being given to the utilisation of cotton seed flour as a means of mitigating, in some measure, the deficiency in the supply of wheat flour and also as affording in some measure a substitute for meat.

The composition of cotton seed flour will naturally depend upon that of the meal from which it is produced. Some samples contain as much as 66.64% of crude protein and fat (of which 10% is said to be fat). G. S. Fraps gives the composition as 51.19% crude protein, 11.40% fat, 22.22% nitrogen-free extract (carbohydrates), 3.05% crude fibre, 7.21% water, and 6.0% ash. It is stated that the nitrogen-free extract of cotton seed meal is composed most largely of raffinose and that it contains no starch.

Messrs. Cross and Bevan give the following analysis of imported cotton seed flour: Albuminoids (N × 6.25) 50.40%, oil and fat 8.77%, digestive carbohydrates 22.79%, crude fibre 4.50%, moisture 8.32%, ash (mineral matters) 5.16%. They report that the sample may be described as a starch-free seed-flour.

It may be said that cotton seed flour contains no starch, about 54% crude protein, and from 7 to 10% of fat, while wheat flour contains a high percentage of starch, from 10 to 12% crude protein, and from 1½ to 2% fat. The coefficient of digestibility of the protein in cotton seed flour is given as about 88% and that of the protein in wheat as about 94%. On the other hand, the digestibility of the fat in the cotton seed flour is about 93% as compared with 90% for the fat contained in wheat flour.

The protein and fat content of cotton seed flour is about 5 times that of wheat flour. It cannot therefore be substituted entirely for wheat flour in making bread (except perhaps under medical advice in cases where a starch-free diet is necessary), but it is eminently adapted for use as a diluent for wheat flour up to one-fourth or one-third of the wheat flour. Trial bakings made in London with various mixtures of cotton seed flour, potato flour, and wheat flour indicated that the best all-round proportions were about 25% of cotton seed flour, about 69% of wheat flour, and about 6% of potato flour (percentages calculated

*An abstract from a paper read before the London Section of the Society of Chemical Industry. Published in the Journal of the Society.

on solids only). Taking the moisture in these loaves at 25%, the crude protein content would be about 16.9% by weight, which is about twice that in an all-wheat loaf, and, indeed, approximates to that of high quality lean meat.

A great number of experiments on feeding cotton seed meal to animals have been made and it is well known that cattle thrive upon a properly balanced cotton seed meal ration. Experiments on the dietetic value of cotton seed flour for human beings have not been carried out for long enough periods of time to enable final conclusions to be drawn, but so far as such experiments have gone, there would seem to be no objection whatever to cotton seed flour as a food for human beings, provided it be intelligently administered.

According to an American authority (Dr. de Loach) it would be safe to supply 20% of the protein we daily consume (or should consume) from cotton seed flour. A mixture of 5% cotton seed flour, 10% potato flour, and 85% wheat flour (percentages calculated on the weight of solids only) would yield about 9% protein on the total weight of the bread, including water.

To produce 350,000 tons of cotton seed flour (which is 5% of our annual consumption of 7,000,000 tons of wheat flour) would require the decortication of about 1,200,000 tons of cotton seed. Bearing in mind that the kernel occupies about 50% of the volume of the whole seed, our British cotton seed oil mills, which now crush upwards of 500,000 tons of cotton seed per annum, would, by suitably modifying their press boxes, be able to deal with 1,200,000 tons per annum (if the decorticating system were employed) without interfering with the treatment of the other oil-bearing seeds now crushed.

With the production of 350,000 tons of cotton seed flour from Upland seed by the decorticating system, there would be produced about 170,000 tons of refined cotton seed oil suitable for the best grades of margarine about 2,500,000 bales of cotton for spinning, about 60,000 bales of high grade linters, and about 250,000 bales of hull fibre and seed lint. The Anglo-Egyptian Sudan would be suitable for the growth of the necessary cotton seed for these products, but it must be borne in mind that the cost of putting the 2,500,000 acres that would be necessary under cotton alone would involve large sums of money, and that the labor required could only be supplied by a population many times greater than that of the Anglo-Egyptian Sudan today.

The admixture of 5% cotton seed flour and 10% potato flour with the wheat flour employed in making our bread would reduce our wheat imports by about 1,050,000 tons, or by nearly 20%.

UTILISATION OF THE SHORT COTTON SEED FIBRES ON THE WOOLLY VARIETIES OF COTTON SEED.

Until recently, these short fibres were entirely neglected, but they are now successfully separated from the hulls by a mechanical process. The short fibres (or hull fibres) have already been employed in very large quantities by the Du Pont de Nemours Powder Company in America, for the manufacture of explosives, and before the outbreak of war, increasing quantities were being annually employed by papermakers in Great Britain and in France in substitution for rags and textile wastes for the manufacture of the higher grade qualities of paper.

Quite recently another machine has been introduced which, it is claimed, will detach the shorter fibres from woolly seed that has already been lightly linted and deliver the fibre in so clean a state that the yield of cellulose obtained therefrom approximates to that of raw long cotton.

It may be asked why the American system has not been adopted in Great Britain. One answer to this question is given in the recently published Bulletin of the Imperial Institute (No. 3 of Vol. XV., July—Sept., 1917) in the following words: "The reason of the backward condition of the oil and seed crushing industry (in Great Britain), taken as a whole, is mainly that it began in the days when oil-cake for feeding cattle was the chief desideratum and the oil a relatively unimportant material, and this has largely determined the kind of seeds crushed."

It is certainly the fact that, speaking generally, British crushers have devoted their attention in the past chiefly to oil seeds giving a comparatively low yield of oil and a high yield of cake. One obstacle to the adoption of the American system by British seed crushers is to be sought in the difficulties attending any attempt to introduce products differing in appearance or character from those for which the demand has been long established. On the other hand it appears that the technical questions involved in modifying the oil mill equipment do not present any serious difficulties, nor would the capital outlay on such modifications constitute a matter of governing importance.

In recent years, and in particular since the outbreak of war, the whole situation has been greatly changed. The demand for oils for the manufacture of margarine and other edible fats which sprang up some ten years or so ago on the Continent, was not at first reflected in this country. The German seed crushing industry, being of comparatively recent origin, commenced with the advantage of up-to-date equipment. Special attention was paid to copra, palm kernels, ground nuts, and other seeds having a high oil content, and in the result, German seed crushers "have not only monopolised to a large extent the crushing of rich oil seeds but have also made inroads into the crushing of cotton seed which, so far as Europe is concerned, had been until the last few years (before the war) practically a British monopoly."

The extent of these inroads may be gathered from the fact that in 1905 94.4% of the exported Egyptian crop came to British mills and in 1913 the proportion had sunk to 51.6% the remainder going practically entirely to Germany.

At first sight, it would seem that the era of working cotton seed is drawing to a close. This is, however, not necessarily the case. Let it be conceded that, in the future oil will be the primary and cake the secondary consideration, and that the richer oil-bearing seeds will come more and more into demand, the fact remains that we must have cotton.

The greater the preferential demand for the richer oil seeds, the more will cotton seed tend to become a drug in the market—at least in the export market. Nevertheless, the intrinsic value of the high grade oil and of the protein and fat content of the decorticated cake, will remain unaltered, and the rise into favor of the richer oil seeds should therefore operate to stimulate activity in the crushing of cotton seed in the countries of origin. The pure oil will always hold its market and the cotton seed cake or meal, or the cotton seed flour obtainable from the pure kernels, should always command a market at a price based upon its high protein and fat content. In view of the fact that the recovery of the short cotton fibre, before and after decortication of the seed, is now a commercially established industry, there is no longer any reason why the crusher should hesitate to leave enough "fuzz" on the woolly seeds to ensure high efficiency in decortication and thus to produce the highest grade of oil and cake.

One mill in this country, at least, has under serious consideration the erection of a decorticating plant with a view to the adoption of this system on a large scale upon the conclusion of the war, when supplies of woolly seed may be expected to become available in even larger quantities than hitherto.

For reasons arising partly out of the increase in the home consumption of cotton in the United States, it is probable that after the conclusion of the war, Great Britain will have to provide a means of crushing very much larger quantities of the woolly varieties of cotton seed than have hitherto been dealt with. Thus, the question of the relative merits of the British and the American methods is likely to become an increasingly important one.

The decorticating system, plus the plant for defibrating the seed (before decortication) and the hulls (after decortication) involves a larger capital outlay per ton of seed treated than the British system. On the other hand, the profit realisable from the treatment of woolly cotton seeds by efficient decortication in combination with judicious linting and defibration of the seed, and defibration of the decorticated hulls, is appreciably higher than that realisable for the products arising from crushing the seed whole, after deduction of the milling costs involved in each system.

In dealing with woolly seed, there can be little question as to the method of milling which should be adopted.

It is clear that, did a decorticating system exist whereby the meats of bald seed could be segregated efficiently from the hull (or shell of the seed) such seed could be turned to more profitable account in that way than by crushing it whole.

Logically, the grading and selection of the seed for planting, the growing and picking of the cotton, the ginning of the seed-cotton, the baling and pressing of the fibre, the linting and defibrating of the seed, the decortication of the seed, the production of oil and cake, the defibration of the decorticated hulls, and the utilisation of the shell-bran should, as far as practicable, be carried out under the control of one organisation in the country in which cotton is grown. Only those practically concerned with cotton cultivation realise what an immense difference it would make if proper attention were paid to the selection of seed and if the production of seed and the milling thereof were in the same hands. Incalculable advantage would also be gained by the country itself, as only such proportion of the products would be exported as were not consumed in the country, the manurial value of the cake fed to cattle alone being an important item from the agricultural standpoint. Having regard to the enormous areas throughout the Empire where climatic conditions favor the cultivation of cotton, there should be room for many such organisations, and opportunities would be afforded for the remunerative employment of practically unlimited capital.

Single-Impulse Instantaneous Photography

A BRIEF account of the development of the method and apparatus for single-impulse radiography is given and a comparison is made of the exposures obtained from (*a*) a single-impulse outfit with mercury dip interrupter and (*b*) Siemens' impulse outfit. It is found that the exposures obtained from apparatus (*a*) are much shorter than those obtained from apparatus (*b*); the better quality of negatives obtained with set (*b*) has been attributed to the greater intensity of the discharge, but it is possible that the longer exposure is the real explanation of the difference. The Coolidge tube is undoubtedly the best and most reliable to use for this class of work because of its great flexibility, its durability, and the great ease of manipulation which it allows. With one tube any number of exposures may be made with the tube emitting rays of varying penetration. Though plates obtained with the screen are good it would be a great help in technique if it could be dispensed with altogether; at present this cannot be done because the apparatus is not powerful enough. An interesting set of experiments demonstrates the effect of passing the rays through the screen on to the film, and the gain in sharpness of the detail when the rays do not pass through the screen but through the glass to the film and on to the contiguous surface of the screen.

Plates exposed by the single-impulse method require to be developed for a longer time than those exposed by the time method. Care must be exercised to prevent fogging by the dark-room light or chemical fog from prolonged development: the plate should not be exposed to the red light for the first 3 to 5 mins. in order to obtain the max. photographic effect. It is indicated that it would be necessary to increase the power of the machine to at least 4 times that at present in use, and for distance work *i. e.*, at 6 ft., proportionately more power would be required. This problem should readily be solved by the electrical engineer, it being merely a matter of calculation and, possibly, experimental work to produce the apparatus satisfactorily. It would be of great value to radiologists if a standard method for the production of high-tension currents could be evolved. Whether it should be produced by the coil or the high-tension transformer is a matter for the engineer. The value of single-impulse exposures is demonstrated in the radiography of children; in infants the detail of bone is excellent, chiefly because the rapidity of the exposure eliminates voluntary or involuntary movements on the part of the patient.—*Note in Sci. Absts. on a paper by R. Knox, Inst. El. Eng.*

Hardness and Viscosity of Varnish

THE varnish maker's practical "thumb-nail test" is inadequate, as it fails to give quantitative expression to the results obtained. The mechanical hardness testers of Laurie and Baly, Jahns, and Clemens measure toughness rather than hardness. The author described a method which would determine true hardness, and which was based on the principle of the hardness of minerals scale, scratching points of various crystals of known relative hardness being used. A method of embodying the use of gelatin points of differing water content and registering results obtained in degrees of water was also suggested. Of the various types of instruments for determining viscosities of the widely differing types of varnishes, those in which force as against time, was the factor determined, are recommended. The author has elaborated a type of viscometer having for its principle the determination of the time taken for a glass of metal ball suspended on one arm of a balance of high moment of inertia to fall a definite distance through the liquid the viscosity of which has to be determined. The times taken under similar conditions in air and in water serve for the standardization of the instrument ("retardation for water"). Viscosity is calculated as time taken in the liquid less time taken in air, divided by the retardation for water. As equilibrium is readjusted after immersion of the ball, a correction is made for specific gravity. In this way values were obtained for four characteristic oils as follows: linseed oil, 7.7; olive oil, 10.5; rape oil, 12.1; castor oil, 200.—*J. Soc. Chem. Ind.*

The Smithsonian "Solar Constant" Expedition to Calama, Chile

By C. G. Abbot, Smithsonian Astrophysical Observatory

As early as 1903 the observations of the Smithsonian Astrophysical Observatory suggested the view that the solar radiation varies over a range of several per cent. within intervals as short as a few days or weeks. We were measuring the radiation of the sun at the earth's surface. The measurements comprised determinations of the heating effect of the solar rays on the blackened surface of the pyrheliometer, which measures all rays of the spectrum as found in "white light," and also the heating effects at all parts of the solar spectrum as detected by the bolometer, including ultra-violet, visible and infra-red rays. We measured at intervals on every clear day as the sun declined from high altitudes near the zenith to low altitudes near the horizon. Thus the rays measured passed through longer and longer paths, according to the obliquity with which they crossed the atmospheric layers, and consequently they grew weaker and weaker as the sun declined lower and lower. From the spectrobolometric measurements, standardized to calories by aid of the simultaneous pyrheliometer measurements, and reduced to zero atmospheric absorption by the method of Langley, we thus determined the intensity of solar radiation as it would be outside the atmosphere at mean solar distance. This has been called the solar constant of radiation. Its average value is about 1.93 calories per square centimeter per minute.

As I have said the results of 1903 at Washington indicated variations of this so-called constant over a range of nearly 10%. Owing to the prevalence of clouds at Washington all too few observations were available. Nevertheless when we compared such as we had with the anomalies of temperature of the North Temperate Zone as represented by meteorological observations at 89 stations, all regions showed a variation of temperature nearly parallel to, and of a proper magnitude to correspond with, the supposed variations of the sun.

In 1905 we transferred the observing to Mount Wilson, California, and with the exception of 1907 we have observed the "solar constant," in that relatively favorable place, usually from June to October of each year. The results have confirmed the apparent variability of the sun. It is impossible to go outside the atmosphere to observe, and we feared that the apparent variability of the sun might have been really due to defects in our estimation of the losses in the atmosphere. To check our work as far as possible we observed in 1908, 1909, and 1910 from the summit of Mount Whitney (4420 meters) the highest peak in the (older) United States. No error dependent on altitude appeared. In 1914 we sent an automatic recording pyrheliometer by sounding balloon to 25,000 meters altitude. The result obtained was trustworthy and agreed with what we expected. All these checks confirmed the accuracy of our work and strengthened our belief in the solar variability.

Meanwhile in 1911 and 1912 I had observed in Algeria while my colleagues observed in California. Unfortunately for the proof of solar variability 1911 was cloudy and 1912 was the year the air was charged with volcanic dust by the great volcanic eruption of Mount Katmai, June 6, 1912. Nevertheless despite this handicap the results left little reasonable doubt that the sun is variable. High "solar constant" values at Bassour, Algeria, coincide with high values at Mount Wilson, California, and vice versa, and equal increments of radiation were found at the two stations independently, notwithstanding that they are separated by one-third the earth's circumference.

In 1913 and subsequently the proof of solar variability was rendered impregnable. We investigated daily the distribution of radiation over the solar image formed by our tower telescope on Mount Wilson. The sun's image is, as you know, unequally bright at centre and edges, so that the curve of its intensity along a diameter takes the form of the letter U inverted. The steepness of the curves of the U varies with wave-length. But we found also that it varies from day to day, and that the variations are such that a greater contrast of brightness between center and edge occurs when the solar radiation as a whole is found to be diminished and vice versa. I suppose the outer layers of the sun vary in transparency. When more opaque they diminish the "solar constant" but as the effect is greatest near the limb of the sun where the oblique path of the ray in the solar layers is greatest, the result is also to increase the contrast. At all events we have found a true variation of the sun, independent of the earth's atmosphere, which coincides in time of its fluctuations with the observed changes of the "solar constant."

Professor Pickering had kindly undertaken pyrheliometer measurements at Arequipa, Peru. These were carried on from 1912 to 1917. They tended to confirm in the more outstanding features the variation of the sun observed at Mount Wilson.

Dr. L. A. Bauer, whose remarkable campaign of magnetic observations lends lustre to the science of our country, has investigated certain minute disturbances of terrestrial magnetism for which no cause had been assigned. He finds them to be closely correlated with the variations of solar radiation we have observed.

Dr. H. H. Clayton, formerly of Blue Hill Meteorological Observatory, now of the Argentine Meteorological Service, has investigated the variations of terrestrial atmospheric temperature and pressure for nearly fifty stations in all parts of the earth. He finds a close correlation of these meteorological variations with the irregular variations we have observed in solar radiation. Equatorial stations show a direct correlation in temperature. That is high solar radiation is followed by high temperature and vice versa. Many temperate zone stations show opposition of variation. Polar stations show direction variation. If these results shall be confirmed and enlarged they bid fair to aid in actual weather forecasting, for the changes are by no means small.

In view of the scientific and utilitarian interest associated with the variability of the sun, I have long desired that several cloudless observing stations might take up "solar constant" work. In 1914 I made a trip to Australia expecting that the Australian Government would take it up. This hope was frustrated by the war.

In 1916 Secretary Walcott appropriated from the income of the Hodgkins Fund to equip and maintain for several years such a station in South America, but owing to the war it was temporarily located in the North Carolina mountains in 1917. The station proved very cloudy, and now it has proved possible though very expensive to go to Chile.

After correspondence with the South African, Indian, Argentine and Chilean meteorological services I became convinced that near the nitrate desert of Chile is to be found the most cloudless region of the earth easily available. Dr. Walter Knoche of Santiago has most kindly furnished two years (1913 and 1914) of unpublished daily meteorological records for a number of Chilean stations. In his judgment and mine the best is Calama on the Loa River, Lat. S. 22° 28′, Long. W. 68° 56′, Altitude 2,250 meters. For the two years the average number of wholly cloudless days is at 7 a. m. 228; 2 p. m., 206; 9 p. m., 299; and of wholly cloudy days, none. The precipitation is zero; wind seldom exceeds 3 on a scale of 12; temperature seldom falls below 0° or above 25° C.

Our expedition, Director Alfred F. Moore, Assistant Leonard H. Abbot, reached Calama June 25, 1918, equipped with a full spectro-bolometric, pyrheliometric, and meteorological outfit of apparatus, as well as with books, tools, household supplies, and everything which we could furnish to make the work successful and life bearable. We are under great obligations to the Chilean Government for facilitating the expedition in many ways, and to the Chile Exploration Company who have given the expedition quarters and observing station at an abandoned mine near Calama. Many others in Antofagasta, Chuquicamata and Calama have been of great assistance.

The apparatus is set up in an adobe building 30 feet square, in which the observers also have sleeping apartments. A 15-inch two-mirror coelostat reflects the solar beam to the slit of the spectro-bolometer. We use a Jena ultra-violet crown glass prism and speculum metal mirrors in the spectroscope. The linear bolometer is in vacuum, and constructed in accord with complete theory for greatest efficiency. Its indications as measured by a highly sensitive galvanometer are recorded photographically on a moving plate which travels proportionally to the movement of the spectrum over the bolometer. Successive bolometric energy spectrum curves each occupying 8 minutes of time are taken from early morning till the sun is high and are thus recorded on the plate. Their intensity indications at 40 spectrum positions are reduced by aid of a special slide plotting machine.

A pair of silver disk pyrheliometers is read simultaneously with each spectro-bolographic determination. Measurements of humidity, temperature, and barometric pressure accompany the bolometric observations. Also a pyranometer is employed to determine the total sky radiation.

The young men find pleasant companions at the great copper mine at Chuquicamata. At present they are boarding with a Chilean family at Calama, but as both are good cooks they may wish to board themselves. The railway and the river both pass the town of Calama, so that there is no such desert isolation as might be feared. To the east are the Andes Mountains. The peaks in that neighborhood rise to 16,000 or 17,000 feet. Some are volcanic but none of these are very near.

We hope the work will be continued for several years at least, and that nearly daily observations may be obtained. The application of the results to meteorology is something which may prove to have great possibilities. To exploit them we must first possess a long and nearly unbroken series of solar radiation observations.—*Proceedings of the Natl. Acad. of Sciences.*

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